PRODUCT ENGINEERING

APRIL, 1952

HIGH PRESSURE AIRCRAFT COMPRESSOR TEST

IN THIS ISSUE — Foam Plastics • Clad Metals for High Temperature • Appearance Design • Needle Bearing Selection • Precision Springs • Stability of Servos

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Sharon, Pennsylvania

VOLUME 23

PRODUCT ENGINEERING

NUMBER 4

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April, 1952 PRODUCT ENGINEERING Vol. 23, No. 4

Published monthly by McGraw-Hill Publishing Company, Inc., James H. McGraw (1860-1948), Founder. **Publication Office, 99-129 North Broadway, Albany 1, N. Y.**

Executive, Editorial and Advertising Offices: McGraw-Hill Building, 330 W. 42nd St., New York 36, N. Y. Curtis W. McGraw, President; Willard Chevalier, Executive Vice-President; Joseph A. Gerardi, Vice-President and Treasurer; John J. Cooke, Secretary; Paul Montgomery, Senior Vice-President, Publications Division; Ralph B. Smith, Editorial Director; Nelson Bond, Vice-President and Director of Advertising; J. E. Blackburn, Jr., Vice-President, Circulation.

Subscriptions: Product Engineering—Subscription Service, 99-129 N. Broadway, Albany 1, N. Y., or 330 W. 42nd St., New York 36, N. Y. Allow ten days for change of address.

Subscriptions are solicited only from executives, engineers and consultants engaged in the design of machinery and other engineering products. Position and company connection must be indicated on subscription orders.

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Single copies 50¢. United States and possessions, $5 for one year, $8 for two years, $10 for three years; Canada, $6 for one year, $10 for two years, $12 for three years; Latin American countries, $15 for one year, $25 for two years, $30 for three years; all other countries $20 for one year, $30 for two years, $40 for three years. Entered as second class matter August 21, 1936, at the Post Office at Albany, N. Y., under act of Mar. 3, 1879. Printed in U. S. A. Copyright 1951 by McGraw-Hill Publishing Co., Inc.—All Rights Reserved.

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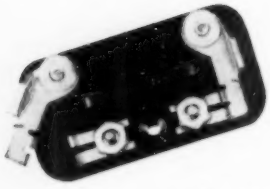
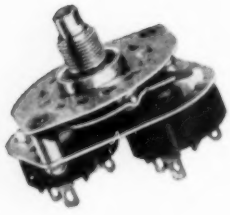
TAKE A LOOK at the four switches shown here. They are examples of the diversified range of switches Mallory is prepared to produce—examples of versatile Mallory design in which dependability of performance and reasonable cost are the primary aims. It will pay you to bring your switch design and production problems to Mallory. Call or write today.



TRANSMISSION SWITCH. Mallory produced this switch to help make possible easy changing of truck gear speed ratios. Large contact area was provided to overcome serious arcing problem caused by high inductive DC load. Wedge-shaped contact helps maintain contact pressure despite vibration.

VOLTAGE CHANGE SWITCH. Simplified design, dependable performance and lower cost are features of this switch that connects electric motor field windings in parallel for 110 volt operation, or in series for 220 volt operation. Constant contact tension and maximum electrical conductivity are insured by stator contacts of silver-plated phosphor bronze. Rugged construction withstands motor vibration.



POWER SUPPLY SWITCH. Two double-pole switches do the work of four single-pole switches in this Mallory-designed switch for use with mobile communications equipment. Assembled from standard parts, it is simpler, lighter and more compact.

TRANSFER SWITCH. For use on airplane fuel tank booster pumps, Mallory developed this switch with a unique design to lengthen contact life . . . assure vital dependability. Spring-loaded contact arm insures uniform contact force and extremely low contact resistance.

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For information on titanium developments contact Mallory-Sharon Titanium Corp., Niles, Ohio.

Highlights

When requesting further information from companies and organizations mentioned in the items below, confusion can be avoided by referring to the issue of Product Engineering in which items appear

NONMETALLIC MATERIALS

DOMESTIC MICA is now being converted by G.E. into a high grade product, Micamat, that has a uniform dielectric strength of 600v per mil. Trick is to pulversize the natural mica and treat it so that the particles cohere. A special machine then rolls the mass into sheets 0.006 in. thick.

HEAT SEALERS on machines that automatically assembly cardboard containers must retain a uniform degree of slipperiness at the heated areas; otherwise the folding and gluing cycle is upset. To prevent binding between carton and heater, the Package Machinery Co. near Springfield, Mass., sprays Teflon on the heater surfaces.

PRESHAPED SECTIONS of glass fabric honeycomb are simplifying the assembly of aircraft rodomes. California Reinforced Plastics Co., Berkeley 10, Calif. precurves the Hexcel material to avoid the buckling that would otherwise occur and then cuts the piece to final form.

LUBRICATING GREASES containing silica jel have an affinity for moisture. Two Canadians have received U.S. Patents 2,583,603-7 which cover a method for waterproofing the silica gel with various alkyd resin components.

SOME "POTTING" MATERIALS are subject to excessive shrinkage when cast around electronic components. The B. G. Forman Co. of Brooklyn, N.Y. reports the Polyform G series solve this problem. Through changes in the formula, the amount of shrinkage can be regulated from a negligible value to a desired small amount as determined by the requirements of different assemblies.

LONGER LIFE will be the key property of both natural and synthetic rubber when it is made according to Monsanto Chemical's new patent No. 2,582,695. Special additions prevent deterioration caused by heat, light, oxygen and flexing.

PLASTIC AUTOMOBILE BODY developed by U.S. Rubber's Naugatuck Chemical Div. and the Glasspar Co. of Costa Mesa, Calif. is molded as a single, 185-lb piece from Vibrin polyester and layers of glass fiber. Rust-proof and dirt-resistant, 0.2-in. thick molding costs about $650 and fits a 100-in. wheelbase chassis.

INSULATING TAPE made from Teflon by Minnesota Mining and Manufacturing Co. is stable from -100 to +500 F and meets Class B and H requirements. Two layers of 3-mil film give dielectric protection at a 5,000-v level; resist most solvents and electrical varnishes.

METALLIC MATERIALS

DYED ANODIC FILMS applied to super-pure aluminum will take a very high luster if two to five percent of magnesium is added. Tests made by the Aluminum Development Association, London W1, reveal the alloy reacts more favorably to polishing and brightening than do less pure alloys.

NICKEL CONTENT of nickel-silver alloy used in the many small flat springs of electromagnetic apparatus can be reduced from 18 to 12 percent without sacrifice in mechanical properties. ASTM Committee B-5 has designated the 12-percent alloy as No. 8 in their Specification B 122.

COBALT-60 is now produced as a series of 19 radiographic sources in strengths from 50 millicuries to 25 curies. Tracerlab, Inc. of Boston reports the gamma energies emitted are 1.17 and 1.33 million electron volts, or the equivalent of a two-million volt X-ray machine.

SPRAYED ZINC OR ALUMINUM is being used as a priming coat for paint on the steel hulls and exposed parts of tuna clippers. Clark Metalizing Co. of Newport Beach, Calif., finds this trick of preventing galvanic action as successful as is the government in its practice of hanging sticks of magnesium next to the hulls of warships.

(continued on page 7)

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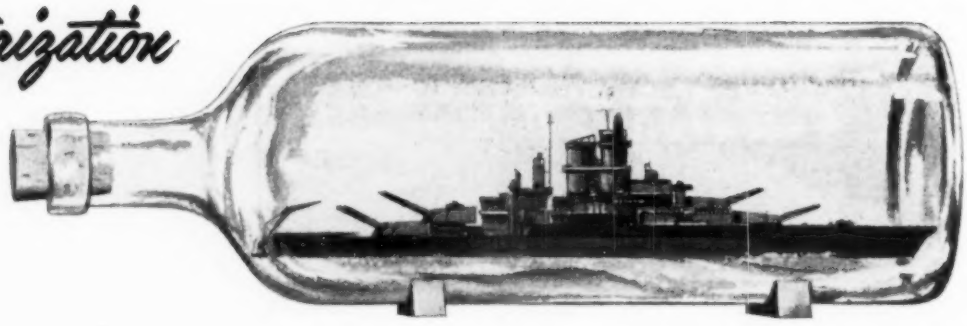
Miniaturization



Mighty Midgets in Plastics

For the newest important developments on the plastics front, look to the intensive miniaturization program underway in the electronics and communications fields. Working, in this case, through the vast resources of RCA, the program calls for intense miniaturization in size, and reduction in weight, of physical components. Idea, of course, is to produce smallest, lightest, assemblies possible–with greatly improved efficiency–for a scope of use impossible with unwieldy old equipment.

What a made-to-order spot for plastics! And for a moulder! The terminal boards, insulators, coil cases and covers (shown here actual size) have tolerances so close that in some instances, they are machined to final dimensions. There are wall sections as thin as .012". Inserts are fine Swiss screw machine plated parts with exacting thread fits assembled to microscopic dimensions. Materials are low-loss mica-filled phenolics.

There's a production story here, too! With such necessary precision, commercial production was at first thought to be impossible. Within three weeks, we produced experimental tooling and a production method using compression and plunger techniques along with a combination of the two. *And then, carefully analyzing our experimental program, we designed and produced production tooling–and are now meeting production quotas and rigid inspection with commercial moulding methods!*

We can't offer you a better recommendation. For small parts–or large ones–we can put lots of experience at your disposal.

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FOR OVER 36 YEARS PLANNERS AND MOULDERS IN PLASTICS

THE TS4140 STEELS are being used as substitutes. In some instances this change is practical, but if brittleness cannot be tolerated, it is better to substitute with boron-treated grades.

RIGID SPECIFICATIONS imposed by Briton's Aircraft Ministry for highly stressed powerplant

castings are met by Z5Z magnesium-base alloy. In addition to 4.5 percent zinc is 0.6 percent zirconium, which is known to reduce porosity through grain refinement. Except in extra large castings, the Z5Z alloy exhibits uniformly good properties throughout a single casting.

PROCESSES

FURNACE BRAZING of stainless steel is difficult because of scale and flux removal problems. Researchers at Armco Steel Corp., Middletown, Ohio, have solved these problems by plating Type 302 18-8 stainless with 0.2 to 0.3 mils of iron. Oxidation is thus prevented so that copper brazing at 2,150 F is possible.

NORMAL TOLERANCES without machining are achieved on light-metal castings by a semi-forging process in which oversize castings are sized or coined in precision dies. In this process used by the Germans for guided missile parts, the castings become slightly wrought and reductions up to 30 percent produce high ductility.

A 31-POUND OIL PAN is being mass-produced in permanent molds at the Continental Motors Corp., Detroit. The aluminum alloy casting measures approximately 38 by 14 by 14 inches. Six to ten pounds of metal per casting are saved and production for two men is 80 per 8-hr shift.

COLD HEADERS are used by Ford Motor Co. to produce 12,500 copper alloy commutator segments in a single hour. Finished parts are automatically separated from scrap on a vibrating transfer chute and a pair of inclined outward-revolving rolls. Scrap drops through between the rolls while the finished parts continue on and drop into a hopper at the end of the rolls.

LICENSES can now be obtained from the Aluminum Company of America, Pittsburgh, for the application of anodic oxide coatings. These finishes cannot be chipped or flaked because they become an integral part of the parent metal.

ROLLING AND SLICING is a description for GE's method of producing stator blades for jet engine compressors. Instead of being hammered from a single piece of stainless steel, blades are first rolled in long strips to the proper air-foil shape and then cut to exact length during assembly.

AN ELECTRONIC "HAMMER" may be a practical means for work-hardening some metals. North American Aviation's Statitron bombards a target and rearranges its structural pattern.

IMPROVED TECHNIQUE for applying a zinc coating to aluminum is assigned to the Philadelphia Rust-Proof Co. in U.S. patent 2,580,773. The aluminum is cleaned and then dipped in a solution containing water-soluble zinc sulphate and hydrofluoric acid. Similar method is used for applying cadmium and tin to aluminum.

COMPONENTS

AIR CONDITIONED CARS will be defying all climates in the near future, according to a spokesman of the Chrysler Corp. He predicted that auto refrigeration systems will utilize mechanical vapor compression, with condenser, evaporator and other essential units located in the trunk.

LATEST TREND in TV tubes is represented in RCA's 17-in. all-glass rectangular tubes with

cylindrical faceplates that reduce reflections in the vertical plane. The Filterglass plates also improve picture contrast by minimizing ambiant light reflections from the phosphor screen.

TINY MAGNETIC HEAD 3/8-in. in dia and 1 in. long permits an increase in the number of heads spaced around the drum in memory storage systems. Ferrite core is non-abrasive for protection of drum coatings. Computer Research Corp. of Hawthorne, Calif. rates the head at 13.8 mh inductance, 11 ohms d-c resistance, 50 ma writing current and 0.4 play back voltage.

OIL MIST PRECIPITATOR made by Trion, Inc. of McKees Rocks, Pa., saves lubricants and reduces hazards in high speed cutting and grinding operations. The mist is charged as it passes through an electrostatic field and attracted to plates of opposite polarity. It then drains into a collecting pan for reuse.

(continued on page 9)

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Scaife research

develops stronger, lighter pressure vessels

The pressure vessels and deep-drawn shapes being made today in the Scaife factory are *better* because of scientific research in Scaife Laboratories. For example, the development of the new Scaife Dura-Lite LP-Gas Cylinder included a complete study of the deep-drawing process, using half-size parts made on the research department press shown above. This procedure, supplemented by complete metallurgical, physical, chemical and specialized studies, permits accurate evaluation of various materials, drawing methods and processing procedure. The result is a better, more serviceable product designed and made on sound engineering principles.

Here is the "big brother" of the press shown at the top of the page. Full-size cylinder-half has been formed in one stroke of the press (see right) and is being removed for processing and assembly.

Starting with a circular sheet of steel—

a cup is formed by a conventional drawing operation.

A continuation of this pressing operation turns the cup "inside out" without removing it from the dies,

completing—in a single stroke—the deep-drawn shape, which becomes a cylinder-half. Shown below is the complete cylinder, a standard container for liquefied petroleum gas. Similar Scaife cylinders are used for freon, acetylene and other materials.

SCAIFE COMPANY

OAKMONT (Pittsburgh District), PENNA.

Makers of Pressure Vessels for Air, Gases and Liquids

FOUNDED 1802

SELF-FEEDING GREASE CUP tells at a glance when a moving part needs to be relubricated. A

stationary piston at the end of tubing screwed into bearing housing fits a cylinder that acts as a reservoir. Spring pressure, plus bearing vacuum, assures continuous grease supply by moving cylinder downward. Manufacturer is the A. L. Watson Co., Milton 87, Massachusetts.

SMALL LUBRICATING PUMP developed for oil burners has anti-friction rollers where vanes are generally used. Milwaukee Hydropower's Magna-Mite has a capacity of 1 1/2 down to 1/4 gpm and a speed range from 300 to 3,600 rpm, yet is only 3 in. in diameter and 6 in. long.

TESTING

CORRECT MEASUREMENT of air temperature outside an airplane moving at 500 mph is made with a vortex thermometer perfected at the Office of Naval Research. A tube extending axially in the air-stream contains a spiral vane which produces a vortex of whirling air. The cooling effect of the low-pressure vortex center cancels the heating effect of compression, regardless of plane speed. Thus, a thermometer placed in the vortex will always give a correct reading.

POCKET-SIZE CALCULATOR does the job of a high-priced electric desk machine, according to Curta Calculator Co., 5543 S. Ashland Ave., Chicago. The Swiss-designed midget adds, subtracts, multiplies and divides; figures square roots, factors, cubes and percentages. Not only that, it carries results to five decimal places.

EXHAUST SYSTEMS do not have to be hammered to locate corroded spots when the Magne-Probe is used. A bridge circuit measures the inductance of a coil for which the core is the metal being tested. Inductance is proportional to the permeability of the core and thus a measure of the heat corrosion in the metal.

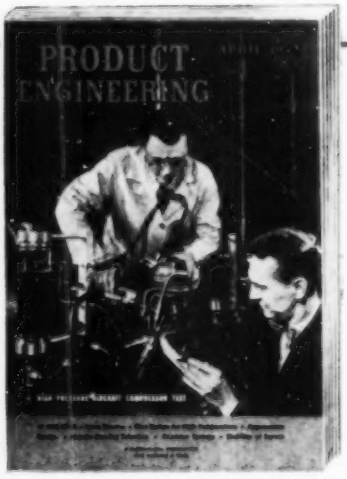
A COMPUTING SECTION has been set up at Battelle Memorial Institute, Columbus, Ohio. One battery of digital computers has already been installed, and another of the same type is being built. The aim of the laboratory is to reduce or replace time-consuming pencil-and-paper work that is part of basic research conducted for various sponsors.

IMPACT RECORDER gives indication of the time, direction and severity of jolts occurring

within an object on a tape moving at one inch per hour. The Impact-O-Graph is expected to be of practical value for determining the right type of container needed to protect a product during transit.

DUAL-HEAD TEST STAND checks various accessories like generators, pumps and compressors, two at a time. Continuous-duty horsepower is from 7.5 to 50; intermittent duty, from 10 to 75 hp. Type VEU-GSDT test unit has a high-speed shaft range from 1,950 to 10,800 rpm, and a low speed shaft range from 1,070 to 5,900 prm. The maker, U.S. Electrical Motors Inc., Los Angeles 54, Calif., supplies adapters to fit all mountings.

A PREFORM MOLDING LABORATORY has been set up in Milwaukee by Pittsburgh Plate Glass to expedite developmental work and customer problems pertaining to Selectron polyester resins.



THIS MONTH'S COVER

Aircraft designers have long recognized the advantages of high pressure pneumatics as a source of power for actuating airplane emergency equipment but the possibilities have never been fully exploited. There has been no compressor available that would meet the weight size requirements of air-borne equipment and still deliver a sufficient quantity of air.

The center of interest in this month's cover is the new high pressure air compressor that Walter Kidde and Company Inc. of Belleville, New Jersey have developed to fill this need. This compressor weighs only 15 lb, yet will deliver 4 cfm at 3,000 psi. It is currently used on the Republic F-84 where air pressure is used to actuate the machine gun chargers, and emergency nose brakes and wing flaps.

Inspecting the compressor after its final run on the test stand are Albertus Schmidlin, chief project engineer on pneumatics and John Kapp (standing), in charge of their compressor development testing laboratory.

Kodachrome by Sidney Karson, McGraw-Hill Studios.

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As Advertised in The Saturday Evening **POST**

THE FASTENERS OF TODAY . . . AND OF THE FUTURE

Perspectives ~ DESIGN AND DEVELOPMENT

ENGINEERS SALARIES

The Office of Salary Stabilization is trying to end job-hopping and pirating of engineers, stemming from the shortage. There are no government manpower restrictions as there were during World War II. So OSS Director Joseph D. Copper is exploring the possibility that the undesirable practices can be discouraged, if not completely wiped out, through suitable salary-control regulations and cracking down on violators.

First OSS target is the engineering firms. A questionnaire is going out to them soon asking for information on compensation and employment practices before Korea and today. This survey will be followed by a similar questionnaire to large companies that employ engineers. The Defense Production Act requires employers to supply the information.

From the answers, OSS hopes to get clues to violators as well as a picture of what the situation is. This will be helpful in drafting a special regulation covering compensation of engineers.

Mobilizer Wilson and the Atomic Energy Commission are reported to be particularly upset about the practices of some engineering firms, and will cooperate in the OSS project.

There have been complaints of some engineering firms hiring engineers from industrial employers and then selling back their services, sometimes to the same employer. This enables the engineer to increase his earnings and the employer to keep the engineer's services.

Accelerated promotions of young engineers and bidding above stabilized salary levels for recent college graduates are other complained of practices. Some companies have told stabilization officials that the price of engineering college graduates is at least $50.00 a month above what most companies are allowed to bid. This situation is being examined also by the Wage Stabilization Board.

THE BIG QUESTIONS

Some of the questions that will be asked by OSS are:

1 Entrance salaries (highest and lowest) of engineers hired within six months of graduation in the six months before Korea, the last half of 1951, and the first two months of 1952.

2 Number of engineers employed and the highest and lowest salaries paid them in each of the three periods.

3 List any individual increases granted in excess of the ten percent "catchup" and six percent "merit" formulas.

4 Describe any bonus plans in effect, including the date when instituted and any modification since the freeze date of January 25, 1951. Also state, for 1950 and 1951, the number of engineers receiving bonuses, the total amount paid in bonuses and the largest bonus paid to any one engineer.

5 List and describe compensation paid to engineers other than salary or bonus, such as commissions, expense or per diem accounts, travel allowances and subsistence.

6 State how many engineers were, in 1951, assigned to industrial or other concerns under contract to perform functions normally performed by engineers in the employ of the concerns.

7 State how many engineer employees your firm has lost in the past year through "pirating."

(continued on page 119)

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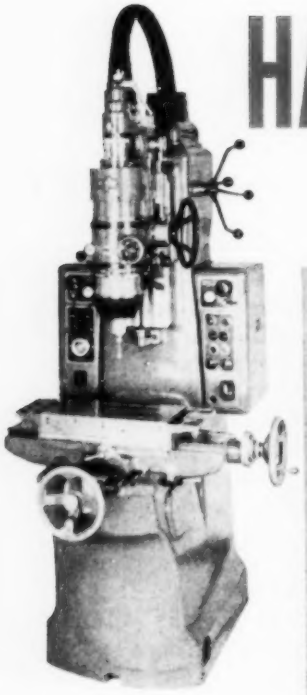
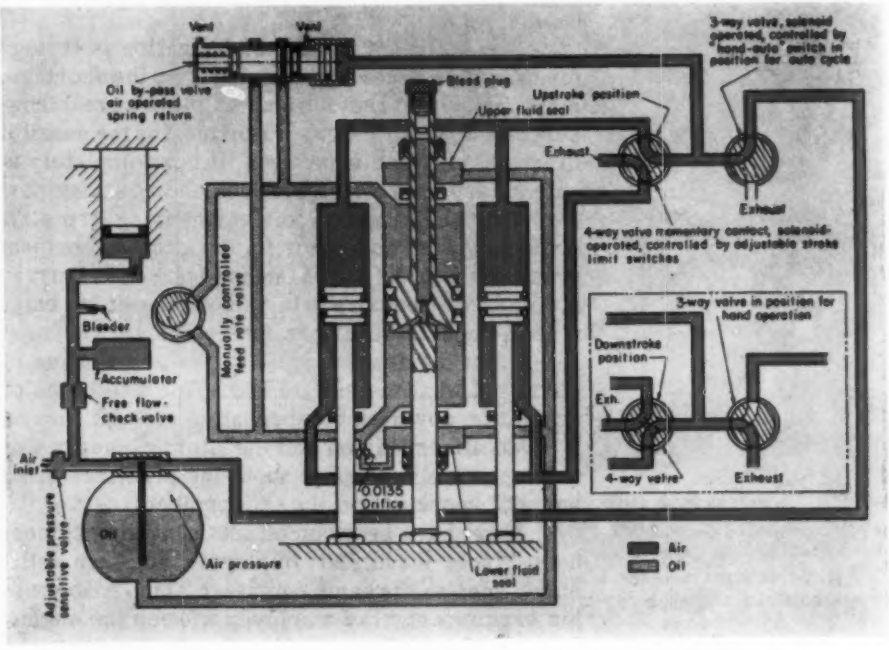
HANNA ELECTRIC VALVE

PROVIDES FOR JIG GRINDER RECIPROCATING ACTION



JIG GRINDER *developed by the Moore Special Tool Company of Bridgeport, Conn., for precision contour and hole grinding.*



THE SCHEMATIC DIAGRAM above shows the circuit used in the Moore Jig Grinder. Power to raise and lower the grinding head is supplied by two Air Cylinders controlled by a Hanna 4-way, double-solenoid valve. This valve, actuated by limit switches, provides the exacting cylinder control necessary for automatic reciprocating movement.

A Hanna Electric Valve was chosen for this application because of its careful manufacture and unusual features. Among these is the tiller principle of operation. This principle involves a short movement of a low mass resulting in maximum speed of operation with minimum shock. The time required for each reversal of the valve is limited to approximately 1/60 second, and its feature of momentary contact (double solenoid models) eliminates the necessity for a holding current providing an ideal valve for limit switch actuation.

The Hanna Electric Valve is precision-engineered—capable of meeting the most exacting demands. It is an example of the quality characteristic of the complete Hanna line of valves and cylinders. For the finest component parts in the machines you design and build, specify Hanna products—they will measure up to your highest standards.

Hanna Electric Valve . . . balanced spool type . . . controlled by solenoid pilot valve and built-in pilot pistons . . . spools stop against Neoprene cushions for silent action . . . solenoid stroke only 3/32" . . . low current consumption enables use of lighter, more economical contactors, relays, etc. . . . available with either single or double heavy-duty solenoids.

For more detailed information on Hanna Electric Valves and Hanna Hand, Foot and Pilot Operated Valves, send for **Catalog 254.**

Hanna Engineering Works

HYDRAULIC AND PNEUMATIC EQUIPMENT . . . CYLINDERS . . . VALVES . . . RIVETERS

1763 Elston Avenue, Chicago 22, Illinois

MATERIALS DECONTROL

Decontrol of metals is gaining support. Controllers believe CMP can end by January. They're beginning to talk about the technique for putting government control in reverse.

Some metals will be kept under tight rationing - such as copper, tungsten, nickel and cobalt. But other key metals, including steel and aluminum, will be turned loose, one by one. Chrome steel is already decontrolled, but nickel steel will be tightly controlled for a long time. There's talk of freeing tinplate, terne-plate and cold rolled strip.

All this results from the arms stretchout. Military's peak spending plans - now changed - prompted the military and civilian producers to lay in big inventories. These now loom large alongside the lower spending plans Truman's budget calls for.

SPECIFIC MATERIALS

You can see an indication of this trend in a quick survey of availability of materials:

Tin: Resumption of U.S. buying has eased the supply picture. Tin is still rated critically short, but the prospect of further imports has temporarily halted plans for additional conservation rules. These plans will be permanently discarded if the government signs additional purchase agreements with foreign producers over the next few months.

Magnesium: Still on the "short supply" list, but not among the most critical. It is in easier supply than aluminum and production is increasing rapidly. Last year it was about 96 million pounds. It is expected to hit 215 millions pounds this year. The first continuous rolling mill for magnesium now being built is expected to make wider and cheaper sheet than is now available.

Cast iron: Gray iron casting over three thousand pounds are scarce but light and intermediate weights are in good supply.

Ceramics: NPA'S steel alloy experts are cooling off on the idea of using ceramic-coated metal in jet engines to relieve the shortage of heat-resistant alloys. They say the problem caused by expansion of the base metal hasn't been solved. They are pinning their hopes now to metal ceramics along the line of German developments in World War II.

Rubber: Synthetic and natural are both in easy supply. Increased export quotas of synthetic indicate that U.S. users are getting all they need. When the government restored a free market in natural rubber March 3, the price was less than half what it was nine months before. Supplies were plentiful at 34 to 32 cents per pound.

FABRICATING CAPACITY

Only shortages of fabricating capacity Washington seems to have heard about are:

Steel: Hot-rolled and cold-finished bars; heavy plate rolling; seamless tubes; heavy structural shapes.

Some new facilities are being built to offset some of these situations. But, in the main, they are being handled by shifts in mill rolling schedules and the like, because the shortage is definitely a temporary thing. Very large-type equipment is involved, and it would be two years before new plants could be built. By that time, we'll be over the hump on all shapes and forms that now are short.

Aluminum: There was some shortage of extrusion capacity needed for aircraft production some time back. But now no one is certain whether there still is a shortage. The aircraft program has been drastically curtailed, with the result that we may have ample fabricating facilities of all types.

There may be shortages elsewhere, but on such items as copper, nickel, zinc and the like you can't say for sure where we would stand on fabricating if we could get all the metal we need.

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Saving Weight

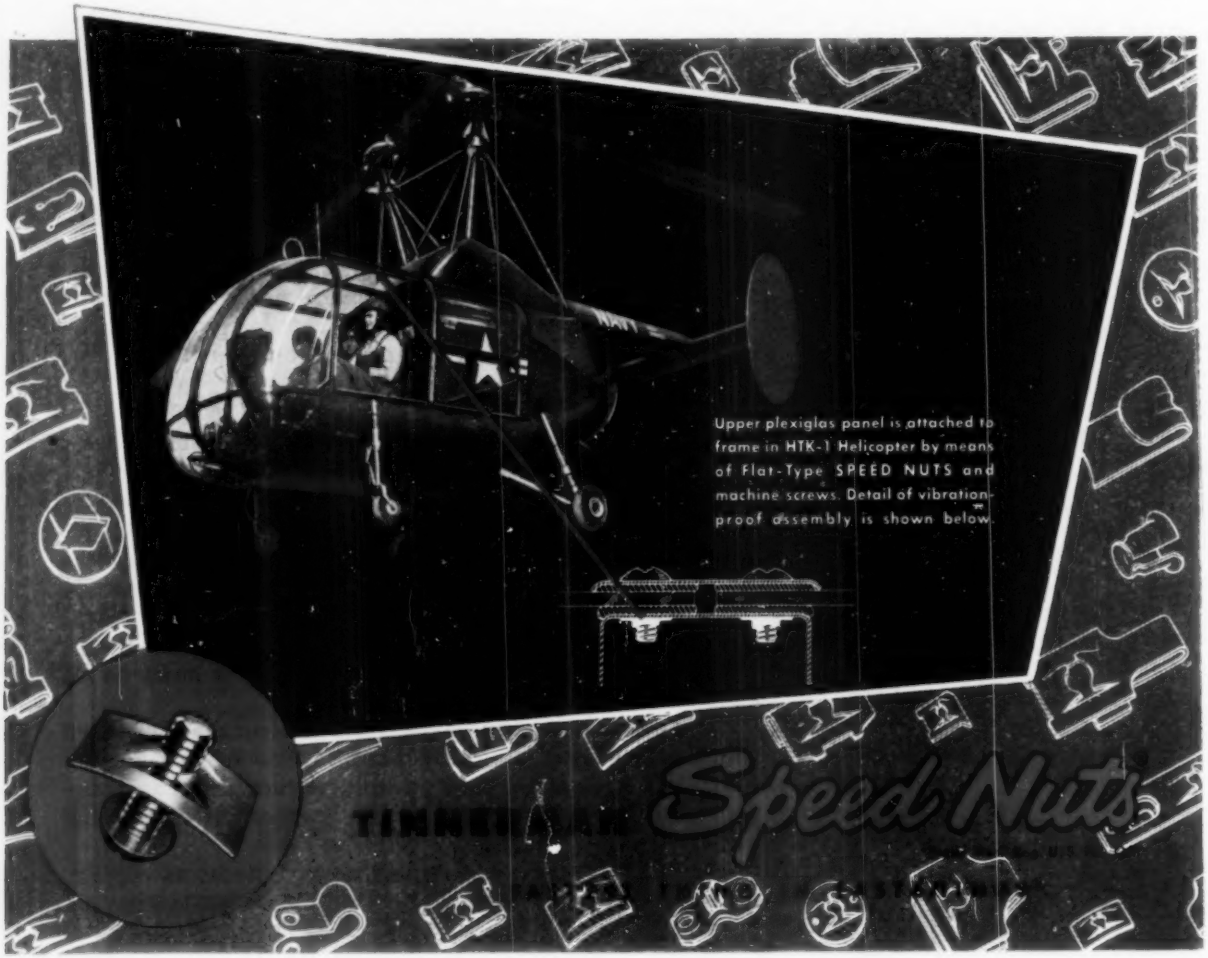
TO SAVE MORE LIVES

How SPEED NUTS made important weight savings attaching plexiglas panels in Kaman Helicopter.

Let the engineers at Kaman Aircraft Corp., Windsor Locks, Conn., tell you how Flat-Type SPEED NUTS performed for them. "We found that lightweight SPEED NUTS provide a large bearing surface which eliminates the need for flat washers under nut. *They reduce the weight up to .31 pounds per hundred when replacing other lock nuts, not including savings on weight of washers.*

"Only one part to handle in assembly means faster, easier attachments. SPEED NUTS are retained in screw-receiving position by finger-tip pressure—no wrench needed to pull down NUTS. *These advantages add up to savings of approximately .15 man-hours per hundred fasteners.*"

If you would like to hear similar savings reports from *your* engineers, specify SPEED NUTS. Your Tinnerman representative can help you determine the right fastener for the job. Call him in soon. And write for your copy of "Savings Stories" Vol. II, Tinnerman Products, Inc., Dept. 12, Box 6688, Cleveland 1, Ohio. *In Canada:* Dominion Fasteners Ltd., Hamilton. *In Great Britain:* Simmonds Aerocessories, Ltd., Treforest, Wales. *In France:* Aerocessoires Simmonds, S. A.—7 rue Henri Barbusse, Levallois (Seine) France.


Upper plexiglas panel is attached to frame in HTK-1 Helicopter by means of Flat-Type SPEED NUTS and machine screws. Detail of vibration-proof assembly is shown below.
Speed Nuts

Putting the Lid on Supply and Demand

THERE ARE MANY ARGUMENTS pro and con on the justification of "salary stabilization." Perhaps the strongest argument against salary stabilization is that wages are not being stabilized, that wage earners have union representation that has been highly successful in unstabilizing the wage scales, and that salary workers have no effective unions. The opposite argument is that if there were no salary stabilization, salaries would skyrocket out of bounds if, as in the engineering profession, there is a shortage of qualified workers.

The Office of Salary Stabilization has not been able to control completely the salaries of engineers. In some quarters much ado is being made over the fact that recent college engineering graduates are being paid as much as 30 percent more in their first job as compared with the pre-Korea figures. However, this apparent increase is more than offset by the higher cost of a college education plus higher living costs. To amortize the cost of a college education over a period of about 13 years requires monthly payments of $50, or at least $60 a month before taxes. This figure should be deducted when judging the adequacy of an engineer's salary.

Some companies, particularly engineering firms, are becoming "notorious" because they are paying higher than "stabilized" rates to engineers. This statement may be in error because some of these firms claim that the Office of Salary Stabilization has never issued definite salary scales, which is true.

According to a recent report from Washington, O.S.S. is going to do something about these high salaries and the "pirating" that is being done by engineering firms. Perhaps something should be done. One solution would be to "stabilize" the salaries at the levels existing in the engineering firms.

Another possible solution to salary stabilization for engineers would be to discard it and let the law of supply and demand take care of it. This would have no measurable effect on inflation, which is the stated reason for salary controls. And it is also to be considered that when supply of engineers exceeds demand, there can be no "stabilization" to maintain the salaries. If supply and demand is not to be allowed to operate in one direction, it should not be allowed to operate in the opposite direction.

Finally, the attempts of O.S.S. to iron out inequalities in engineers' salaries in different industries and geographical areas has been ineffective. Summing it all up, salary stabilization of engineers is serving to make an engineering career economically unattractive at a time when many more youths should be attracted to it in order to meet the shortage.

Admittedly the whole problem is too big to be solved satisfactorily and no one man can have the answer. However, there must be quite a few design engineers who have definite ideas on this matter.

G. F. Yodenkoltz

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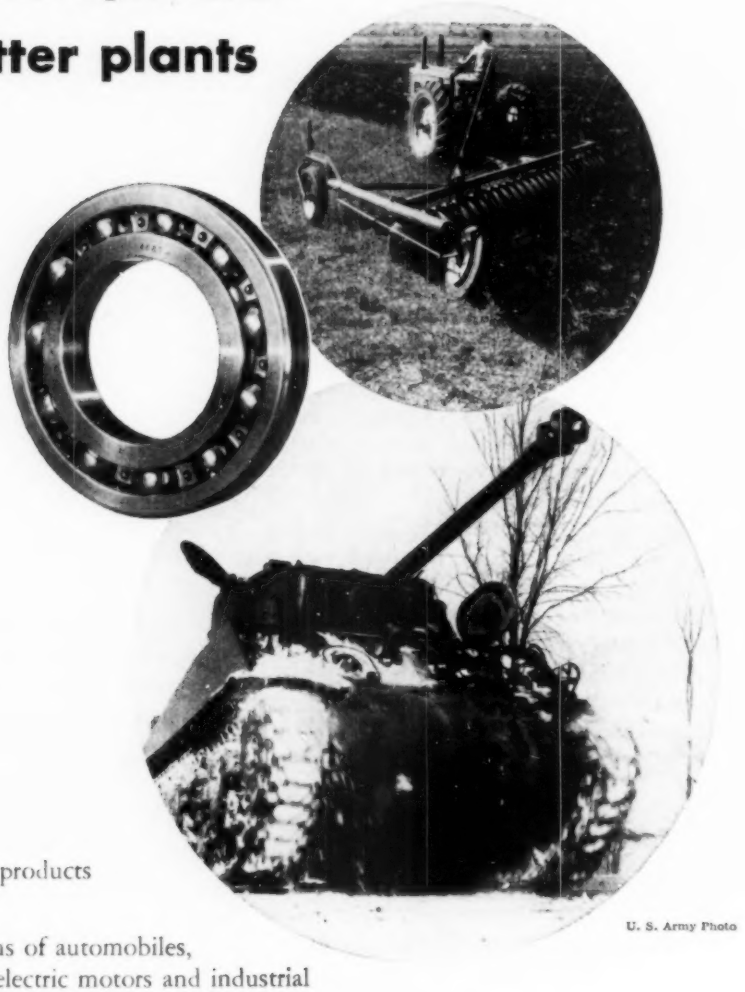
New Departure operates guns-and-butter plants



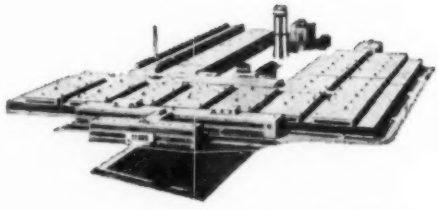
U. S. Army Photo

Ball bearings are essential to the products of our industrial might.

The ball bearings that serve millions of automobiles, trucks, tractors, farm implements, electric motors and industrial machinery are of the same materials, the same heat treatment, the same methods of precision manufacture as those required for mechanized warfare and electronic instruments. Thus conversion from one to the other at New Departure is largely a matter of changing the emphasis on types and sizes.

The productive capacities of the world's largest ball bearing factories are your assurance of the best possible production of your requirements.

New Departure's engineers and vast resources for research are freely at your disposal.



New Departure's plant at Sandusky, Ohio, where ball bearings are produced for *both* industry and the Armed Forces.

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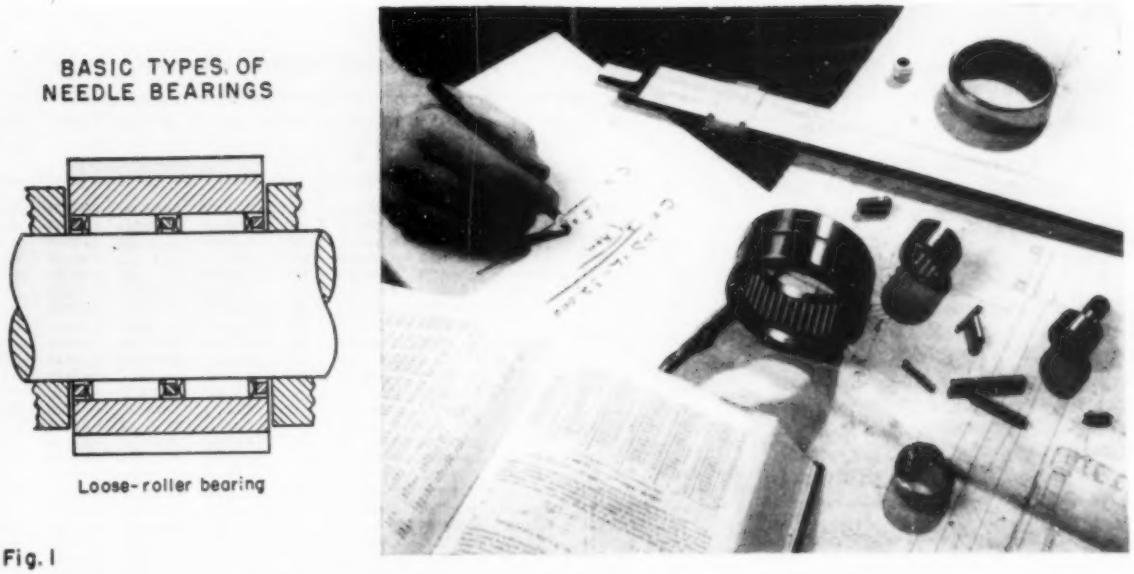
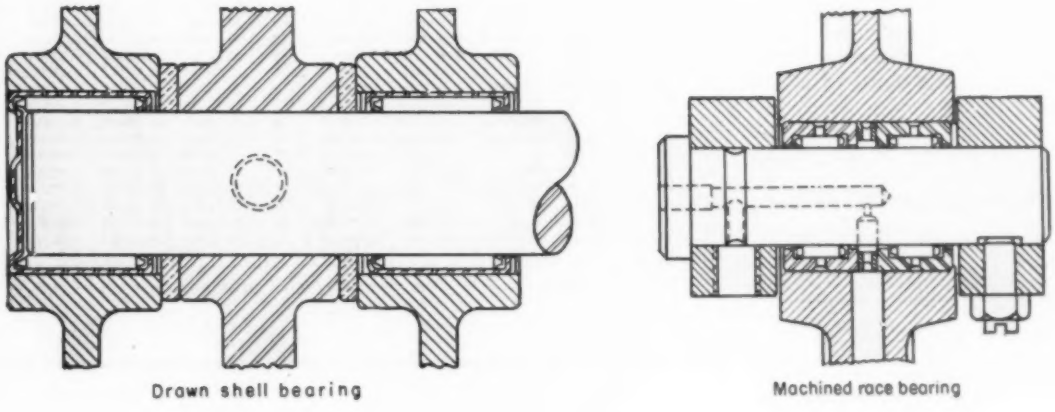


Fig. 1



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Key Factors in Selecting

Needle Bearings

P. R. GLAZIER
The Torrington Company

TO DETERMINE WHICH TYPE of needle roller bearing should be used in a given application, various questions must be answered. Is the housing and/or shaft hardened? How large can the over-all diameter of the bearing be? Can the rollers be retained axially? Is assembly a problem? How is lubrication to be provided?

Though needle roller bearings are manufactured in many forms, there are three basic classifications into which those in common use fall. The basic types are: The loose roller bearing, which has no integral races or retaining members; the drawn-shell bearing, which consists of a drawn case-hardened shell that retains the rollers; and the machine-race bearing, which has machined, hardened and ground races and the rollers in a unit assembly. Fig. 1 shows the differences in construction of the three types and also demonstrates the basic proportions of needle rollers. Good proportioning calls for rollers of diameter approximately 10 percent of the pitch diameter and of length at least four times the roller diameter. The roller-diameter-to-pitch-diameter ratio is not fixed however. Where space is limited and speeds are low, the ratio can be made as low as 2½ percent. When the bear-

ing is to be used for high rotational speeds, the ratio should be kept high. For oscillating motion, particularly heavy loads, lower ratio should be used.

Loose Needle Roller Bearing

The loose-needle roller bearing should be used only when the shaft and outer race bore are hardened and where there are retaining members for locating the rollers endwise. The retaining surfaces should be smooth, hard and unbroken, and both should be fixed to the same race to avoid cross retainment. In applications meeting these conditions and where roller assembly is not difficult, unretained needle rollers constitute a bearing that is inexpensive, small in section and, at the same time, of high capacity.

As there are many different types of loose roller applications, it is necessary to manufacture needle rollers with different types of ends. The main types are shown in Fig. 2. The spherical end is most commonly used where no lip retainment is required. When the roller must be retained by a lip,

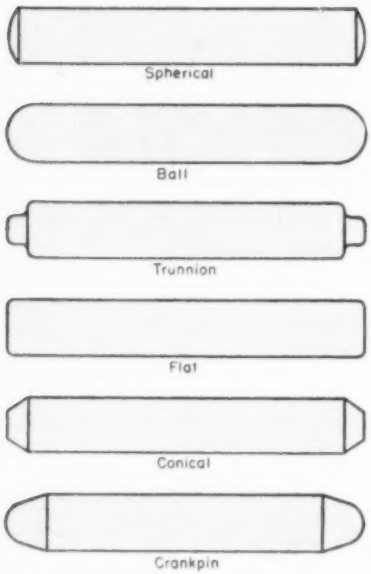


Fig. 2—Shape of needle roller ends is determined by type of retainment.

either a trunnion or conical end should be used. To clear a fillet, such as a crankpin fillet, either the crankpin or ball end can be used. Flat ends are used when the roller is to be lip-guided. Also when the roller is large in diameter and is short, the flat end is used to obtain maximum effective length and consequently maximum capacity.

To obtain the maximum capacity of the needle bearing assembly, the hard-

Table I—Needle Bearing Constants

N	K	K − 1	N(cc)* / π	N(cc)* / (K − 1)π	N	K	K − 1	N(cc)* / π	N(cc)* / (K − 1)π
6	2.00000	1.00000	0.000191	0.000191	44	14.01754	13.01754	0.00140	0.000108
7	2.30477	1.30477	0.000223	0.000171	45	14.33559	13.33559	0.00143	0.000108
8	2.61313	1.61313	0.000254	0.000157	46	14.65365	13.65365	0.00147	0.000107
9	2.92380	1.92380	0.000286	0.000149	47	14.97171	13.97171	0.00150	0.000107
10	3.23607	2.23607	0.000318	0.000143	48	15.28979	14.28979	0.00153	0.000107
11	3.54947	2.54947	0.000350	0.000137	49	15.60788	14.60788	0.00156	0.000107
12	3.86370	2.86370	0.000382	0.000133	50	15.92597	14.92597	0.00159	0.000107
13	4.17858	3.17858	0.000414	0.000130	51	16.24408	15.24408	0.00162	0.000107
14	4.49395	3.49395	0.000445	0.000128	52	16.56219	15.56219	0.00165	0.000106
15	4.80973	3.80973	0.000477	0.000126	53	16.88031	15.88031	0.00169	0.000106
16	5.12583	4.12583	0.000509	0.000123	54	17.19844	16.19844	0.00172	0.000106
17	5.44219	4.44219	0.000541	0.000122	55	17.51657	16.51657	0.00175	0.000106
18	5.75877	4.75877	0.000573	0.000121	56	17.83471	16.83471	0.00178	0.000106
19	6.07553	5.07553	0.000605	0.000119	57	18.15286	17.15286	0.00182	0.000106
20	6.39245	5.39245	0.000636	0.000118	58	18.47101	17.47101	0.00185	0.000106
21	6.70951	5.70951	0.000669	0.000117	59	18.78916	17.78916	0.00188	0.000106
22	7.02667	6.02667	0.000700	0.000116	60	19.10732	18.10732	0.00191	0.000105
23	7.34394	6.34394	0.000732	0.000116	61	19.42549	18.42549	0.00194	0.000105
24	7.66130	6.66130	0.000765	0.000115	62	19.74366	18.74366	0.00197	0.000105
25	7.97873	6.97873	0.000795	0.000114	63	20.06183	19.06183	0.00200	0.000105
26	8.29623	7.29623	0.000828	0.000113	64	20.38001	19.38001	0.00204	0.000105
27	8.61379	7.61379	0.000860	0.000113	65	20.69819	19.69819	0.00207	0.000105
28	8.93141	7.93141	0.000890	0.000112	66	21.01638	20.01638	0.00210	0.000105
29	9.24907	8.24907	0.000922	0.000112	67	21.33457	20.33457	0.00213	0.000105
30	9.56677	8.56677	0.000955	0.000112	68	21.65277	20.65277	0.00216	0.000105
31	9.88452	8.88452	0.000986	0.000111	69	21.97096	20.97096	0.00220	0.000105
32	10.20230	9.20230	0.001020	0.000111	70	22.28917	21.28917	0.00223	0.000105
33	10.52011	9.52011	0.001050	0.000111	71	22.60737	21.60737	0.00226	0.000105
34	10.83795	9.83795	0.001080	0.000110	72	22.92558	21.92558	0.00229	0.000105
35	11.15582	10.15582	0.001110	0.000110	73	23.24379	22.24379	0.00232	0.000104
36	11.47372	10.47372	0.001150	0.000110	74	23.56201	22.56201	0.00236	0.000104
37	11.79163	10.79163	0.001180	0.000109	75	23.88022	22.88022	0.00239	0.000104
38	12.10957	11.10957	0.001210	0.000109	76	24.19844	23.19844	0.00242	0.000104
39	12.42752	11.42752	0.001240	0.000109	77	24.51666	23.51666	0.00245	0.000104
40	12.74550	11.74550	0.001270	0.000109	78	24.83488	23.83488	0.00248	0.000104
41	13.06349	12.06349	0.001310	0.000108	79	25.15311	24.15311	0.00252	0.000104
42	13.38149	12.38149	0.001340	0.000108	80	25.47134	24.47134	0.00255	0.000104
43	13.69951	12.69951	0.001370	0.000108	81	25.78956	24.78956	0.00258	0.000104

*(cc) = 0.0001 in. per roller. For other values of (cc) multiply figures in column by value desired.

SAMPLE CALCULATION: A loose needle roller bearing is to have an inner race (shaft) diameter (D) of approximately 1¼ in. and a width of 1 in. Taking 10 percent of (D), the roller diameter (d) becomes ⅛ in. Though either Eq (2) or Eq (3) can be used for making initial calculations, Eq (3) is preferable because the approximate value for (D) is known. Neglecting the terms $N(cc)/\pi$ and (dc), which have a very small net value, Eq (3) becomes

$$D = (K - 1)\, d$$

Substituting known values

$$1.25 = (K - 1)\, 0.125$$

or

$$(K - 1) = 10.00$$

The nearest value of ($K-1$) in Table I is 9.83795. The number of rollers (N) from Table I is therefore 34.

The final calculations for the bearing are then derived from Eq (2). To systematize the computations, the following tabulation can be used:

(a)	Given	d	0.1250 (max)
(b)	Table I	K for 34	10.83795
(c)	(a) × (b)	Kd	1.3547
(d)	Table I	N (cc)/π for 34	0.00108 (min)
(e)	(c) + (d)	PD	1.3558
(f)	Given	d	0.1250 (max)
(g)	(e) − (f)		1.2308
(h)	Table II	dc	0.0004 (min)
(i)	(g) − (h)	Inner race OD	*1.2304 (max)—1.2299 (min)
(j)	(e) + (f)	Outer race ID	*1.4808 (min)—1.4814 (max)

* See Table III for tolerances.

Table II—Diametral Clearance (dc)

The diametral clearance to be allowed depends upon the use. If the bearing is in a rotating application, the following values based on shaft diameter are recommended. For other or unusual conditions, the bearing manufacturer should be consulted.

Shaft Dia, in.		Clearance (dc), in.	Shaft Dia, in.		Clearance (dc), in.
Over	Includ'g		Over	Includ'g	
0	3/4	0.0003	2 3/4	3 1/4	0.0008
3/4	1 1/4	0.0004	3 1/4	3 3/4	0.0009
1 1/4	1 3/4	0.0005	3 3/4	4 1/4	0.0010
1 3/4	2 1/4	0.0006	4 1/4	4 3/4	0.0011
2 1/4	2 3/4	0.0007	4 3/4	5 1/4	0.0012

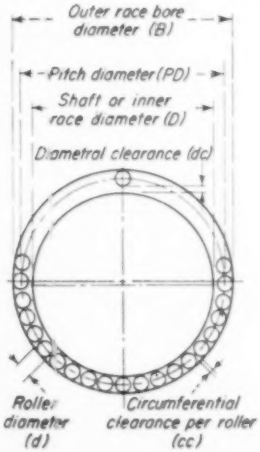
Table III—Shaft and Outer Race Bore Tolerances

The tolerances listed below are presented as practical limits of shop practice and good bearing performance. If greater tolerances are required for manufacturing purposes, the outer race bore maximum can be increased or the shaft diameter minimum can be decreased.

Shaft Dia, in.		Tolerance, in.		Outer Race Bore, in.		Tolerance, in.	
Over	Includ'g			Over	Includ'g		
0	3/4	+0.0000	−0.0003	0	1 3/16	+0.0005	−0.0000
3/4	1 3/16	+0.0000	−0.0004	1 3/16	2	+0.0006	−0.0000
1 3/16	2 1/8	+0.0000	−0.0005	2	3 1/4	+0.0008	−0.0000
2 1/8	3 1/4	+0.0000	−0.0006	3 1/4	4 3/4	+0.0010	−0.0000
3 1/4		+0.0000	−0.0007	4 3/4		+0.0012	−0.0000

The desired bearing width being 1.0 in., a 125L1000 roller is chosen from the SAE Standard for loose rollers. Dimensions for this roller are 0.1250—0.1248 in. by 1.000—0.980 in. These tolerances are standard for loose rollers.

Capacity of this bearing is obtained from Eq (1) in which the effective roller length, L, is the minimum overall length less the two ends. Since the radius on the ends of the roller is about equal to roller diameter d, $d/4$ is subtracted from the overall length. Thus, the capacity C in pounds for 100 rpm is


Outer race bore diameter (B)
Pitch diameter (PD)
Shaft or inner race diameter (D)
Diametral clearance (dc)
Roller diameter (d)
Circumferential clearance per roller (cc)

$$C = \frac{(32{,}000)\ (1.3558)\ (0.980 - 0.031)}{\sqrt[3]{100}}$$

$C = 8{,}880$ lb

Note: All dimensions in inches

Where C = capacity in pounds, L = effective roller length in inches, N = number of rollers and $K = 1 \div \sin 180°/N$, basic equations are:

Eq (1): $$C = \frac{32{,}000\ (PD)\ L}{\sqrt[3]{\text{rpm}}}$$

Eq (2): $$PD = Kd + \frac{N\ (cc)}{\pi}$$

Eq (3): $$D = (K - 1)\ d + \frac{N\ (cc)}{\pi} - (dc)$$

Eq (4): $$D = PD - d - (dc)$$

ness of the inner and outer races must be at least R_c 60. Any reduction in this hardness reduces the capacity, and this reduction is somewhat greater in proportion than the reduction in hardness, especially at the upper end of the hardness range. A reduction in the hardness of the shaft to R_c 50 reduces the capacity of the shaft to 50 percent of the roller capacity, whereas a reduction to R_c 40 reduces shaft capacity to 18 percent of the roller capacity.

To utilize the full bearing capacity, there must be good distribution of the load on the shaft and outer race. Uniformity of loading is a function of shaft and outer race alignment or deflection; alignment depends on the accuracy of manufacture, while deflection can be kept to a minimum by selecting a shaft diameter large enough to carry the bearing load without excessive deflection. To avoid difficulty, the slope of the shaft should not exceed 0.0005 in. per inch. Also, if a couple or over-turning load is imposed, two paths of rollers should be used to provide stability and, consequently, a more even load distribution on the shaft and outer race.

Drawn Shell Unit Type Bearing

The drawn shell type of needle bearing consists of an accurately-formed, hardened shell that surrounds a full complement of hardened and ground trunnion-end rollers. The shell also acts as the hardened outer race, as well as the retaining member. This arrangement not only overcomes the problem of roller assembly but also provides retainment for lubricant and a built-in, hardened outer race for use in housings that are not easily hardened. The inner race or shaft must also be hardened if overall bearing capacity is to be realized. This type bearing is small in cross-section and its capacity is approximately two-thirds that of the loose-roller bearing, assuming the same roller length and shaft diameter.

Drawn shell bearings are purposely made oversize on the outside diameter so that they can be pressed into and be sized by a housing of the correct bore. With this type fit, no auxiliary retaining members such as shoulders, snap rings or spacing tubes are needed, nor should they be used because they are a source of damage to the shell lips. As the bearing depends upon a correct housing bore for sizing, the housing must be sufficiently thick to size the bearing without being distorted by stress built up during press-fitting. Split housings are not satisfactory because they do not correctly

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size the bearing. Also, the housing must be designed so that heavy radial loads on the bearing will be transmitted to a wall or supporting ribs. For a low-tensile housing such as die cast material or low-strength aluminum, it may be necessary to reduce the housing bore slightly to allow for some ironing effect as the bearing is pressed into place.

In pressing the needle bearing into a housing, proper assembly tools should be used. These tools must incorporate a properly designed punch or pusher to insure good alignment between the bearing and housing bore, and to prevent damage to the bearing.

As stated for the loose-roller needle bearing, full capacity of the drawn-shell type is gained only when the shaft is hardened. But some applications call for operation of the bearing on a shaft that is softer than the full R_c 58. The

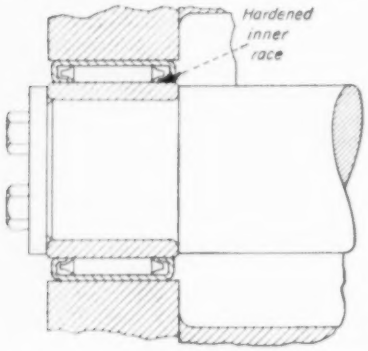


Fig. 3—A separate hardened inner race is added to a drawn shall needle bearing assembly when hardening of shaft is impractical. Inner race must be clamped as shown if it is a slip fit on the shaft.

capacity of the shaft is reduced as the hardness decreases. A shaft of approximately R_c 47 has only 50 percent of the bearing capacity; a decrease of hardness to R_c 40 reduces the capacity to 25 percent of capacity. A cold-rolled steel shaft has only two to three percent of the bearing capacity.

Where it is impractical to harden the shaft, a hardened and ground inner race can be incorporated. With a slip fit on the shaft, the inner race should be retained. This can be done in various ways such as by clamping against a shoulder, Fig. 3. It is also possible to press fit the race to the shaft. But care must be exercised that too great an interference fit is not used because this condition will cause an increase in the outside diameter of the race and a consequent decrease in diametral play in the bearing.

The statements above concerning the load distribution as regards shaft and outer race misalignment also apply to the drawn-shell bearing. A single bearing should not be used where a couple or overturning load is present. Two bearings mounted side-by-side should be used.

Machined-Race Bearing

As compared to the drawn shell type needle roller bearing, the machined-race type has an outer race of heavy section. Generally, the race is manufactured of a case-hardening steel, but it can also be made from a through-hardening steel.

This type of bearing is made in many forms, four of which are shown in Fig. 4. The first type shown consists of trunnion-end rollers retained in the outer race. The main difference between the application of this particular type bearing and the drawn shell bearing is that the former does not depend upon the housing bore for its final size. Therefore, it is pressed into the housing bore with less press fit. In some cases, such as split housings, it is possible to use them with a slip fit in the housing, but then auxiliary members such as snap and spacer rings must be used to locate the bearing endwise.

The uses of the machined-race bearing are quite similar to those for the drawn-shell bearing. However, this type cannot be used where the space available is limited because of its somewhat greater section. The ends or faces of the bearing are also of heavy section. Consequently, the faces can be used for end location in conjunction with stationary thrust washers, which are properly relieved at the bore.

The facts already given for drawn-shell bearings concerning the reduction in shaft capacity with reduction in hardness also apply to this type of bearing. Actually, the percentage loss is greater because of the higher rated capacity of the machine race bearing. Thus, if it is impractical to harden the shaft, a hardened and ground inner race should be used.

The previous comments concerning shaft misalignment also apply. Again, the somewhat greater capacity of this bearing necessitates a shaft large enough in diameter to carry the full capacity of the bearing without deflecting.

The second type of machined-race needle roller bearing shown in Fig. 4 is made up of spherical-end rollers assembled between hardened and ground inner and outer races. The assembly is retained by washers fastened to the inner race.

This particular bearing is designed and manufactured primarily for heavy loads and oscillating motions such as those encountered in aircraft. The outer-race section being relatively thin, the bearing can be pressed into the housing. The inner race must be clamped so that the washers are backed up. This same type of bearing is also manufactured with an extra thick outer race for heavy rolling loads. Generally, this bearing is used at slow speeds such as would be encountered when used as an aircraft flap-track roller.

The capacity of this bearing is generally determined by the strength of the outer race. However, to utilize the full capacity of the bearing, the track or cam surface must be hardened to approximate R_c 60. Any hardness less than this generally limits the overall capacity to the capacity of the track.

For those applications where it is difficult to obtain good alignment at assembly, this bearing is modified to incorporate a self-aligning feature. Fig. 4 shows the self-aligning housing that allows the outer race to align itself during assembly.

The fourth type of machined-race needle bearing shown in Fig. 4 is designed and manufactured for a specific application. This is the cam roller bearing which consists of an outer race, rollers and retaining member, with a stud substituted for the usual inner race. Such an arrangement results in a cantilever mounting as is conventional in cam roller design.

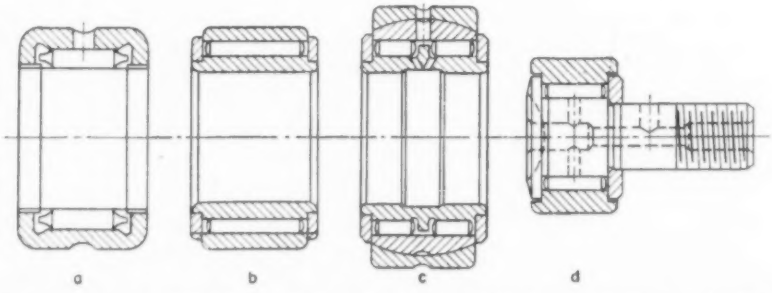


Fig. 4—Typical machined-race needle roller bearings include: (a) Rollers retained in hardened and ground outer race; (b) unit assembly—outer race, inner race, rollers and end washers; (c) self-aligning; and (d) cam roller.

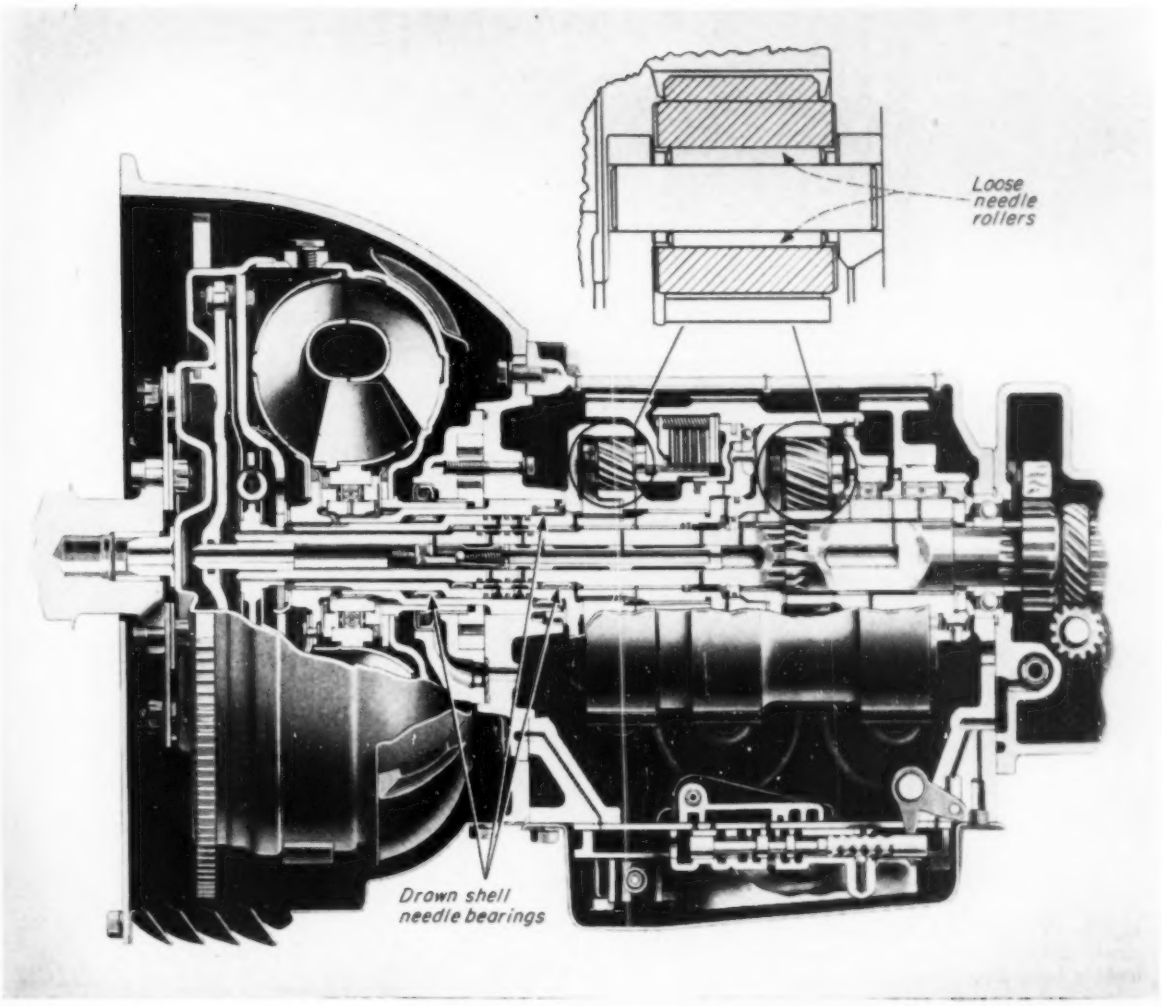


Fig. 5—Loose needle roller bearings are used in planetary gear sets of automatic transmission because shafts and gears are hardened and space is limited. Drawn-shell bearings are used where housing bore is not hardened or to simplify assembly. A Studebaker transmission is shown.

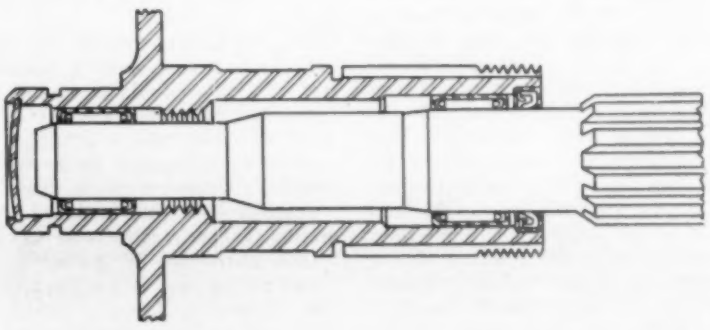
Applications of Needle Bearings

The loose-roller needle bearing is well suited for use in automotive transmissions because the shafts and gears are already hardened and the volume of production is such that special fixtures can be economically built for loading the rollers.

The automatic transmission shown in Fig. 5 has unretained needle rollers in the planetary gear assemblies. Relatively little space is required and the gear diameter is kept to a minimum, resulting in an over-all reduction in the size of the transmission. Drawn-shell bearings are also used because the housing bore is not hardened.

An illustration of how the features of the drawn shell type needle bearing can be used to good advantage is shown in Fig. 6. This shows a drawn shell type bearing applied to the pilot position on the clutch shaft of a fluid drive coupling. The bearing is ideally suited to this application because of

Fig. 6—Drawn-shell bearings are well suited to clutch shaft of fluid drive coupling. Advantages are relatively small outside diameter, capacity to retain lubricant and no necessity for positioning shoulders or retaining rings. Also, the curled-in lips act as lubricant retainers.



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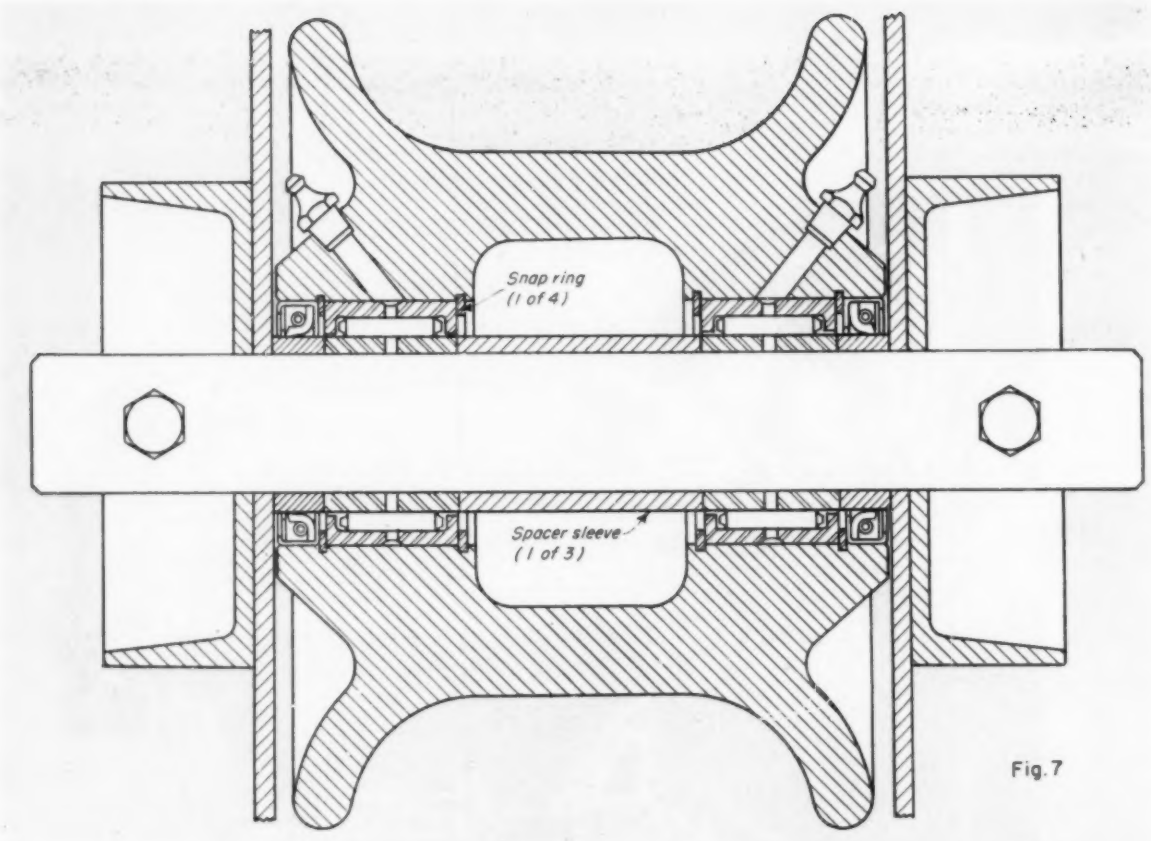

Fig. 7

Fig. 7—Two machined-race bearings generously spaced handle off-center loads in cable sheave. Snap rings and spacers keep the races in position.

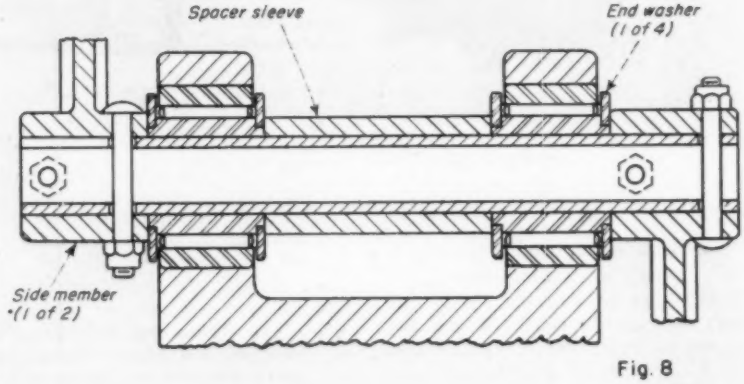

Fig. 8

Fig. 8—End washers and inner races of machined-race bearings in aircraft flap mechanism are clamped between side members and spacer sleeve.

its small outside diameter and, also because it will remain in position without installing snap rings or other retaining members. In addition, the curled-in lips provide simple but effective retainment for lubricant.

A typical application of one type of machined race bearing is the cable sheave in Fig. 7. Two bearings spaced well apart are used because the load is often off center. The snap rings used to retain the bearings in the sheave simplify the machining because the bore is straight with no shoulders. The shaft being unhardened, the inner races are clamped endwise with spacers.

The thicker section of the machined race bearing is not a disadvantage in this application because the section of the sheave itself is large. Also, with the thicker section, it is possible to incorporate garter spring type seals without a recessed bore.

Another type of machined race bearing is used in the aircraft flap extension mechanism shown in Fig. 8. Here, the bearing is simply pressed into the housing. In many aircraft installations, the outer race is staked in place by forcing some of the housing down and over the outer race rounding. The end washers and inner races are clamped between the side members and a spacer sleeve. With this type of bearing, it is imperative that the washers be backed up to carry locating thrust loads. These loads are therefore carried by the plain surfaces between the washers and outer races.

Needle roller bearings are also well adapted for use in assemblies such as steering gears, crank systems, gear pumps, spring suspensions, governors, clutch pilots and crane wheels.

Stainless Clad Copper For High Temperature Service

JOSEPH KINNEY JR.
President, American Cladmetals Company

Stainless clad copper offers for high temperature service, a combination of the high thermal conductivity of copper with the corrosion and heat resistance of stainless steel.

WITH FEW EXCEPTIONS, stainless steels are the poorest heat conductors of all constructional metals. They have about one twentieth of the thermal conductivity of copper and about a third that of carbon steel.

The low heat conductivity of stainless is demonstrated in cooking utensils. Because heat conductivity is low, the heat spreads so slowly laterally that a flame impinging against one side of the stainless sheet causes a hot spot at that point. This characteristic of stainless is a distinct disadvantage in its use for cooking kettles of all kinds, ironers, stoves and wherever else good uniform heat conduction is required or highly desired.

Greater lateral thermal conductivity is also of great value when stainless steel is used in parts such as combustion chamber liners for jet engines, gas turbines, tail cones, exhaust manifolds and similar parts. In such applications it is highly important that the heat impinging upon the sheet be spread laterally so that there will be no hot spot or heat formation that might cause buckling, warping or cracking.

Stainless clad copper combines in one sheet the high thermal conductivity of copper with the corrosion and high-temperature resistance of stainless. The copper core, which is usually about 30 percent the total thickness of the clad sheet, serves to spread the heat at the instant it strikes the sheet and also increases the rate of heat conductivity as compared to a solid stainless sheet of equal thickness. In many practical applications, the high rate of lateral heat conduction results in a much greater heat transfer because the heat conduction is spread over a much greater area. Fig. 1 schematically shows heat conduction through solid stainless and stainless clad copper sheets of equal thickness.

Tests were conducted by Mr. C. T. Evans, Jr., Chief Metallurgist of the Elliott Company to determine the lateral heat conductivity of various metals and sheet constructions. Strips of the metals under test were placed in a furnace and extended out through the door, as shown in Fig. 2. All the test sheets were 2 in. wide and 26¼ in. long. The results of the tests are given in Fig. 3 and 4. As shown by the curves, the highest rate of lateral conductivity occurs when the core is about one half the total thickness of the sheet.

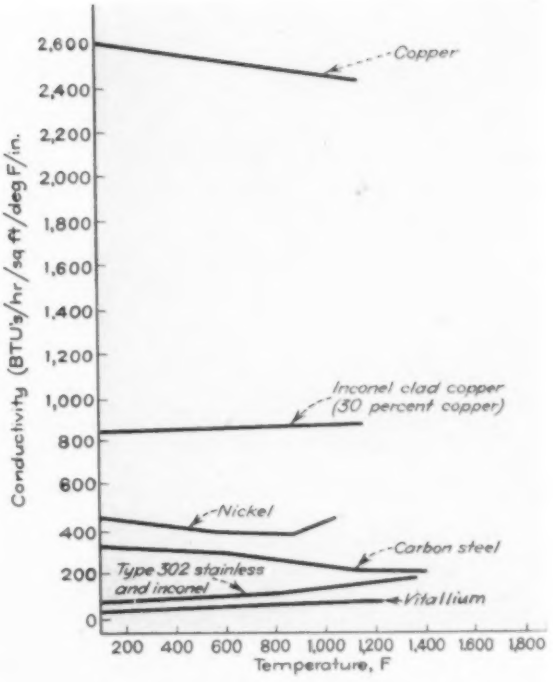

Fig. 1—The low rate of heat conduction in stainless prevents the heat from spreading, causing a hot spot. In the stainless clad sheet the high heat conducting copper core spreads the heat stream.

The fact that the lateral conductivity of the 50 percent copper core stainless clad is higher than that of solid copper is readily explainable. The stainless cladding is a partial heat insulator. In the clad sheets the heat cannot escape from the surfaces as quickly as from solid copper sheet. Furthermore, the bright stainless surface is also a relatively poor radiator of heat. The heat insulation and the slower heat radiation of the stainless clad sheets cause a higher temperature differential between the advancing "heat wave" and the cold metal. Thereby the rate of heat flow increases.

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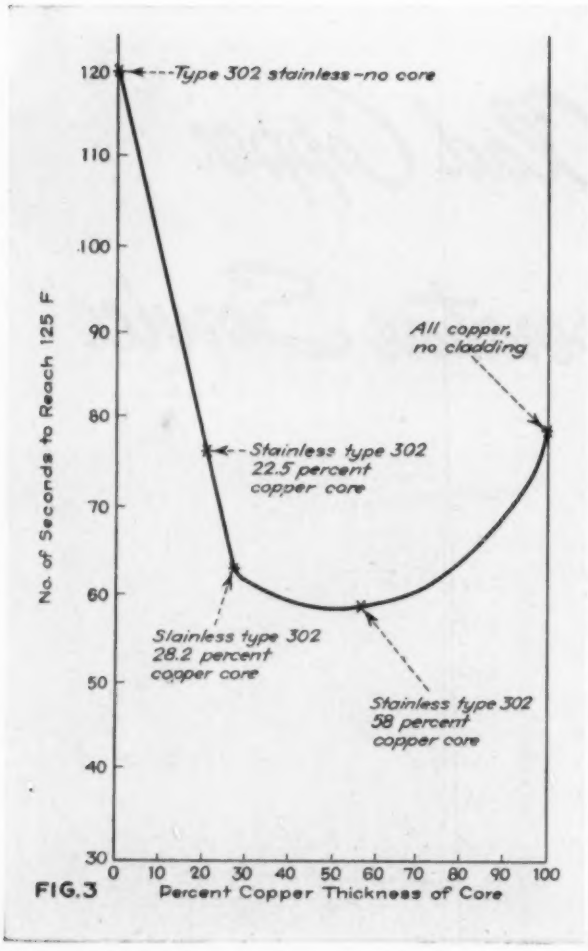


FIG. 3

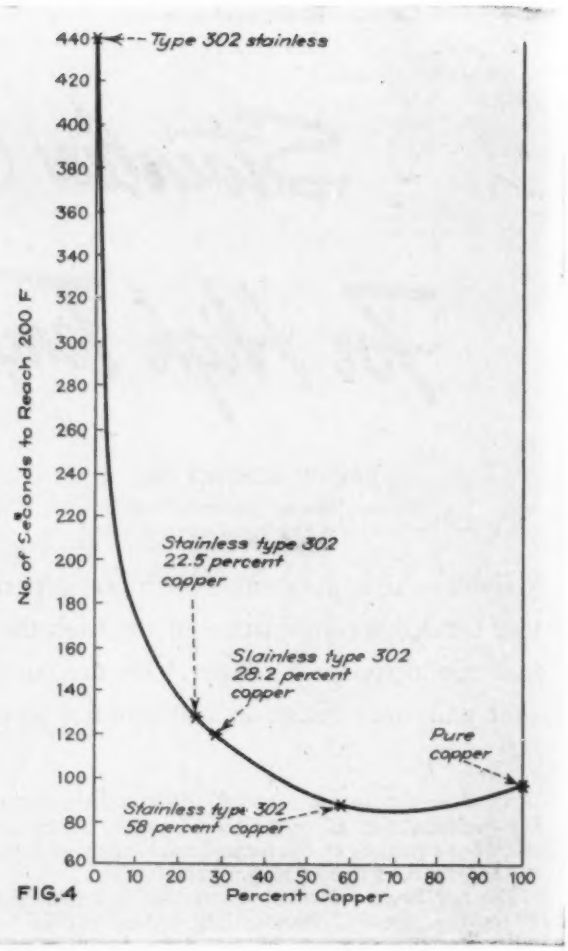
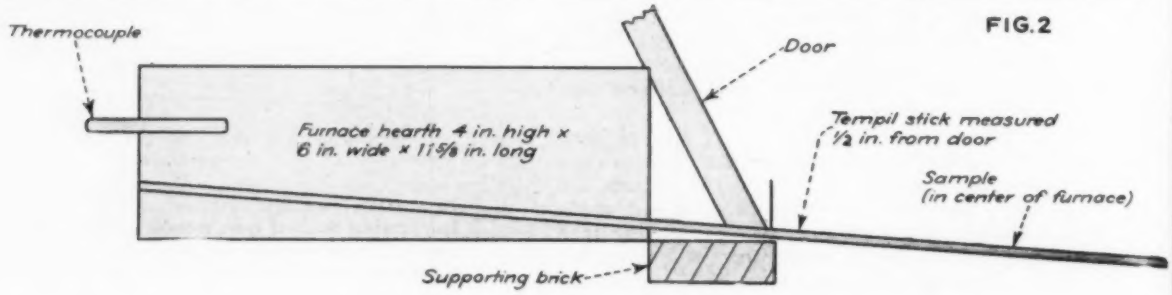


FIG. 4

FIG. 2


Thermocouple
Door
Furnace hearth 4 in. high x 6 in. wide x 11⅝ in. long
Tempil stick measured ½ in. from door
Sample (in center of furnace)
Supporting brick

Applications Data

In general, the corrosion resistance of the stainless steel cladding will determine the corrosion resistance of the laminate. However, because of the relatively low melting point of copper (1,981 F), this clad metal should not be specified for applications where the maximum temperature will exceed 1,800 F, even though the particular type of stainless cladding is able to withstand 2,000 F in continuous exposure to air. If the metal surface is exposed to a chemical laden atmosphere, the maximum allowable temperature may be considerably less. The maximum allowable temperatures for various types of stainless steels are as follows:

AISI Types 302, 304, 316, and 347—1,600 F.
AISI Types 309, 310, and Inconel —1,800 F.

Copper exposed to air begins to oxidize at about 750 F, forming a semi-protective film that retards the penetration of the oxidation. Even at 1,500 F, in still air the penetration will be only about 0.045 in. in 744 hr. or 31 days Therefore in most applications it is not necessary to protect the copper core that is exposed on the cut edge of the clad sheet. But if such protection is desired or required, there are several simple methods that can be used.

If protection against oxidation of the copper is required the edges of the sheet can be "seal welded". In this process the edges of the clad metal are first pickled, the copper being eaten back about $\frac{1}{32}$ in. Stainless edges are then rolled to pinch the edges together which are then Heliarc welded. No filler rod is used.

Sometimes the pickling and edge pinching operations are omitted and filler rod is used in the welding operation.

Instead of seal welding the edges, the calorizing process can be used. Calorizing diffuses aluminum into copper to form an alloy of high oxidation and corrosion resistance. The three methods most generally used in calorizing are the powder method, the cold dip method and the spray metal method. The first is a patented method employed by the Calorizing Company of Wilkinsburg, Pennsylvania who process sheets and articles. The cold dip method was developed largely by General Electric Company.

In the "spray metal" method aluminum is sprayed against the edges, using a standard spray gun, after the edges have been roughened somewhat with a file. The first spray coat is made about $\frac{1}{16}$ in. thick. The sprayed aluminum coating is then treated with a solution of approximately 20 percent water glass in water. Then the edge of the sheet is heated to 1,400 F and kept at that temperature for $1\frac{1}{2}$ hr. during which the copper diffuses into the aluminum. An aluminum-copper alloy that has high corrosion resistance is obtained.

Allowable Working Stress

For rough estimating purposes, the strength of stainless clad copper sheets at room temperatures can be taken as the strength of a sheet of solid stainless having a thickness equal to the total thickness of the laminated sheet less $\frac{1}{2}$ the thickness of the copper core. For strength in the ranges from 500 to 1,500 F, the $\frac{1}{2}$ factor becomes $\frac{2}{3}$. Thus, on a standard 30 percent copper core, the strength of the clad sheet at 500-1500 F will be 80 percent that of a solid sheet of stainless and at room temperature (100 — $\frac{1}{2}$ x 30) or 85 percent.

For design purposes, the allowable stresses for long time service at elevated temperatures are given by the curves in Fig. 6. Thermal expansion characteristics are given by the curves in Fig. 7 for copper, types 347 and 310 stainless, and Inconel. For most purposes it is satisfactory to work with the values of the cladding material.

Workability

No unusual difficulties are encountered in working or machining stainless clad copper. In general, the workability characteristics are approximately the same as those of the cladding. The copper core however, gives the laminated material greater ductility and formability. Unusually deep draws are possible and it is not necessary to anneal as often between draws. To prevent excessive stretching, hold-down pressures should be less.

In shearing and blanking operations on stainless clad copper sheets, the cutting edges must be kept clean and sharp. Blanking die clearances should be close or the metal will drag over the sheared or blanked edges.

Spinning may be accomplished at somewhat higher speeds than would be used for stainless or at about $\frac{1}{2}$ the speed used on solid copper.

Grinding and buffing uses the same procedure as used for the cladding metal.

Anneals between forming or drawing operations should be done at 1,650 F if "pebbling" or "orange peel" is to be avoided. Where this effect is of no consequence, as in most high temperature applications, an annealing temperature application of 1,800 F should be always given if the part is to be used where it will have long-time exposure to temperatures of 1,200 F or higher.

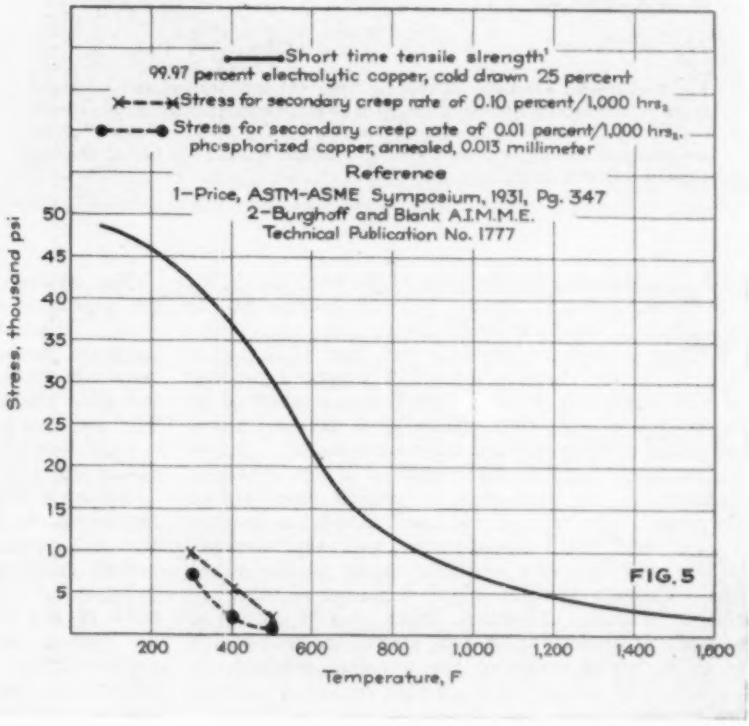
Time of anneal varies with size of part, gage of metal and similar factors. A rough general rule is to hold the part at the annealing temperature for three minutes for gages up to 0.020 in. and add one minute for each

Fig. 2—Arrangement of thin samples in the furnace to determine the relative lateral heat conductivity of various metals and sheet constructions. Point of measurement is 4 in. outside the hearth.

Fig. 3—Lateral conductivity tests of stainless, stainless clad copper and copper strips 0.080 x 2 x $26\frac{1}{2}$ inches. Approximately $11\frac{1}{2}$ in. of sample in hearth at 850F. Time required in seconds to reach a temperature of 125F at a point 4 in. outside of hearth was measured.

Fig. 4—Lateral conductivity tests of stainless, stainless clad copper and copper strips with furnace at 1250F. Time required in seconds to reach 200F 4 in. outside the hearth was measured.

Fig. 5—Effect of temperature on the properties of copper. As can be seen from this curve, copper has relatively low high temperature strength.



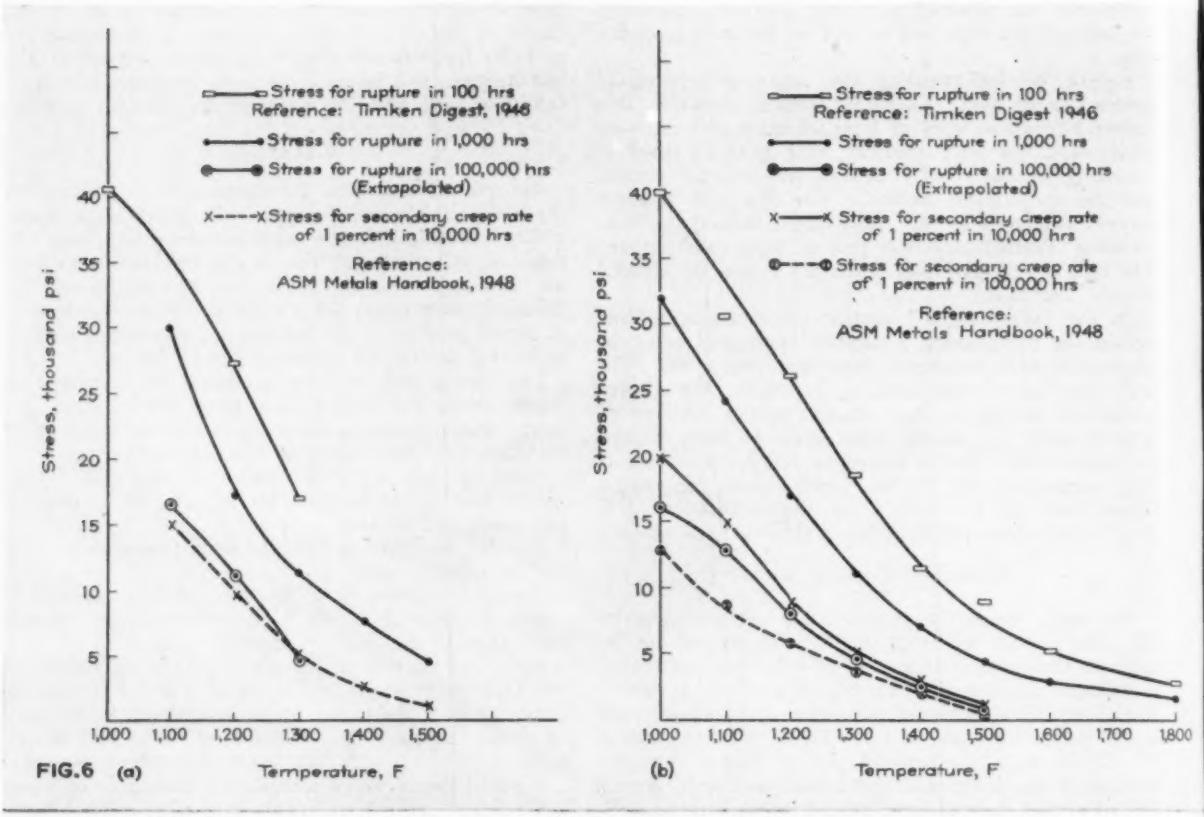


FIG.6

Fig. 6—(a) High temperature design curves for annealed type 347 stainless. (b) High temperature design curves for annealed type 310 stainless. (c) High temperature design curves for annealed Inconel. These are the most popular heat resistant materials used for cladding. In design work allowance must be made for the copper core.

Fig. 7—Thermal expansion of copper, types 347 and 310 stainless steel and Inconel. For most purposes of design it should be satisfactory to work with the values of the cladding material, neglecting the usually higher thermal expansion of the copper core. Type 347 stainless actually has higher thermal expansion than copper.

Fig. 8—Setup for welding stainless clad copper to permit the weld to be made at the bottom layer of stainless with a minimum of copper being melted. Beveling the edges to a 90 degree included angle helps prevent excessive copper pickup. When the proper gap between the pieces to be welded is prepared, the bottom layer of stainless can be fused, and then the metal frozen with a chill bar beneath the joint. The molten metal will then fill the gap in the copper layer. A minimum of copper pickup will be encountered be-

0.010 in. additional total thickness of the part.

Induction annealing cannot be used because of the high electrical conductivity of the copper.

Pickling procedure is identical with that which would be used for the cladding metal. A suggested pickling for scale removal is 5 min at 150 F in a solution of 13 percent nitric acid (42° Baumé), 6 percent hydrofluoric acid (60 percent) and the balance water.

In welding stainless clad copper in a butt joint, the conditions in the weld must be studied from various viewpoints. The type of rod used should be designed to give weld metal analysis that will give strength, ductility and corrosion resistance, equal to the parent metal. Ordinary 18-8 can absorb 4 percent of copper in solution without deleterious effect on its corrosion resistance or its ductility, in fact, a small copper addition up to 4 percent enhances the corrosion resistance to sulphuric acid of the 18-8 stainless steels, as well as making these metals less subject to work hardening.

The welding procedure used must minimize the copper pickup so as to hold it within a safe 4 percent limit. To accomplish this, the current used must be the minimum current that can achieve proper fusion. The copper in the core, because of its high heat conductivity, has little tendency to melt down in the weld puddle. The heat is carried away from the weld puddle at such a rapid rate that the stainless molten metal casts itself against the copper with a minimum of fusion.

Assuming that this condition represents the factual limitations, it is logical, therefore, to develop a fitup that will permit the stainless weld to be made on the bottom layer of stainless with a minimum of copper being melted. When a joint is made with the two sections of the clad metal close together, the only way the bottom layer of stainless can be fused is to melt the copper which, on a close fitup, lies between the arc and the bottom layer. It is necessary that a wider gap be used between the sections to be welded, so as

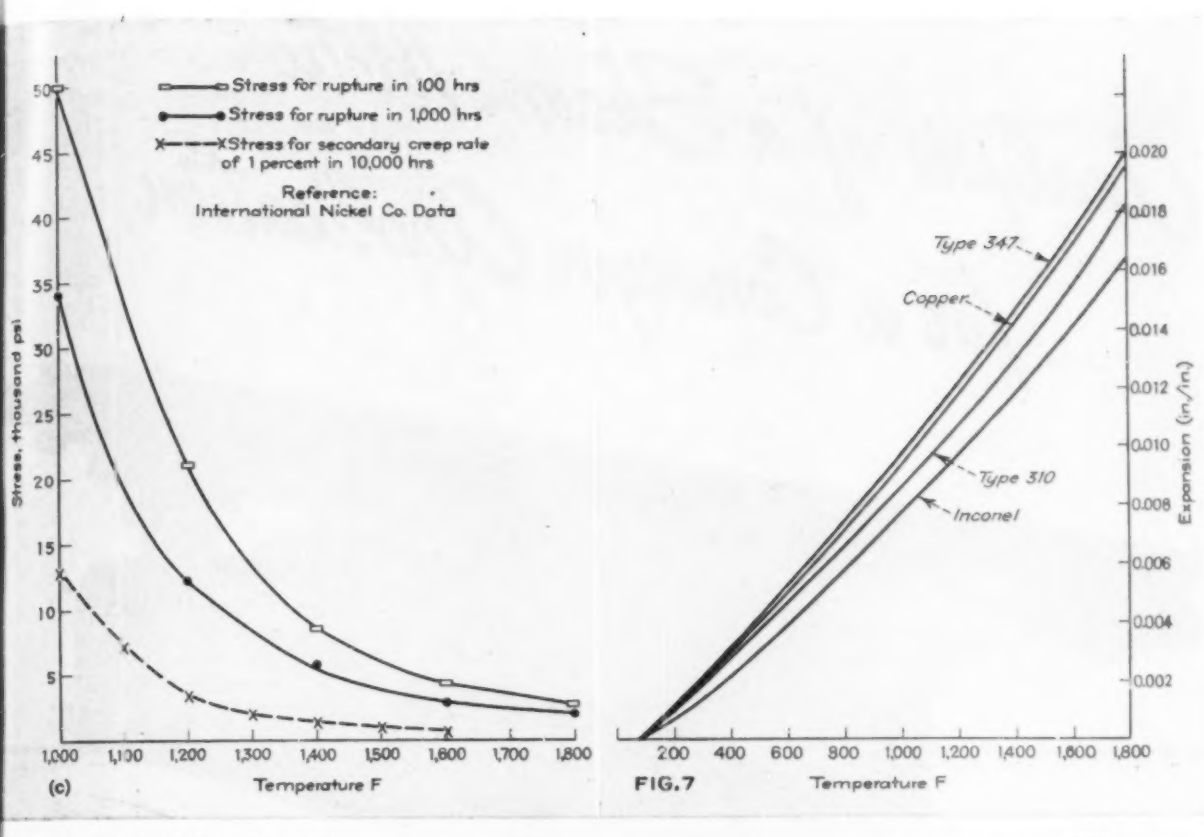


FIG. 7

cause of the chilling effect of the copper on the molten metal in the puddle. The top layer of stainless will then be fused because of the relatively poor conductivity of the stainless and its tendency to fuse into the weld puddle rather than disperse the heat of the puddle laterally away from the welded seam.

Accurate control of current is necessary to give proper fusion. Use of short arc and reversed current is suggested. The welding rod should have as high a nickel content as is available.

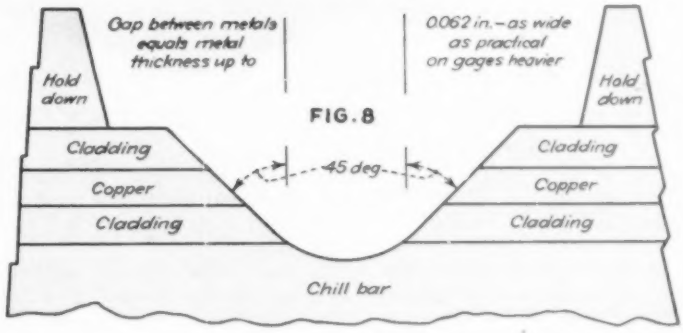


FIG. 8

to permit the arc to fuse the bottom layer of stainless without having to melt through copper. Fig. 8 shows the setup.

The current to be used should be accurately controlled and the voltage-amp characteristics should be the minimum that will give proper fusion. The use of $\frac{3}{32}$ in. or smaller electrodes coated for direct current is recommended. When welding stainless clad copper, a very short arc should be used and the current should be reversed as in welding solid stainless.

It is well known that nickel and copper will go into solution in all proportions, so a high nickel bearing rod should be used. It is suggested that either Inconel or 80 nickel, 20 chrome analysis rod be used regardless of the type of cladding being welded. With a high nickel content, the copper pickup has less effect than in the case of the lower nickel stainless alloys. The welding rod best suited to a particular job must be developed in connection with the gages of the material and the design of the joint. A combination of these factors along with shop practice will determine the proper rod to be used.

Clad copper should be welded in a jig incorporating a chill bar. This chill bar in the heavier sections may be copper with a groove below the seam, machined about $\frac{1}{4}$ as deep as it is wide.

In all gages, it is desirable to bevel the edge to be welded so as to simplify the welding of the bottom stainless. When welding heavier gages, it is desirable to make a multiple pass weld. The first bead is designed to fuse the bottom layer of stainless. After depositing the first bead, the weld is cleaned throughly and subsequent layers of weld are fused to the previous bead. In this way, the weld groove may be filled with filler metal with a minimum of copper pickup.

Resistance spot and seam welding can be done by using the same procedures as for the cladding metal. Some adjustments of pressure and current will be required, but the operation is substantially the same.

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Analysis of a Shaker Motion for a Conveyor Application

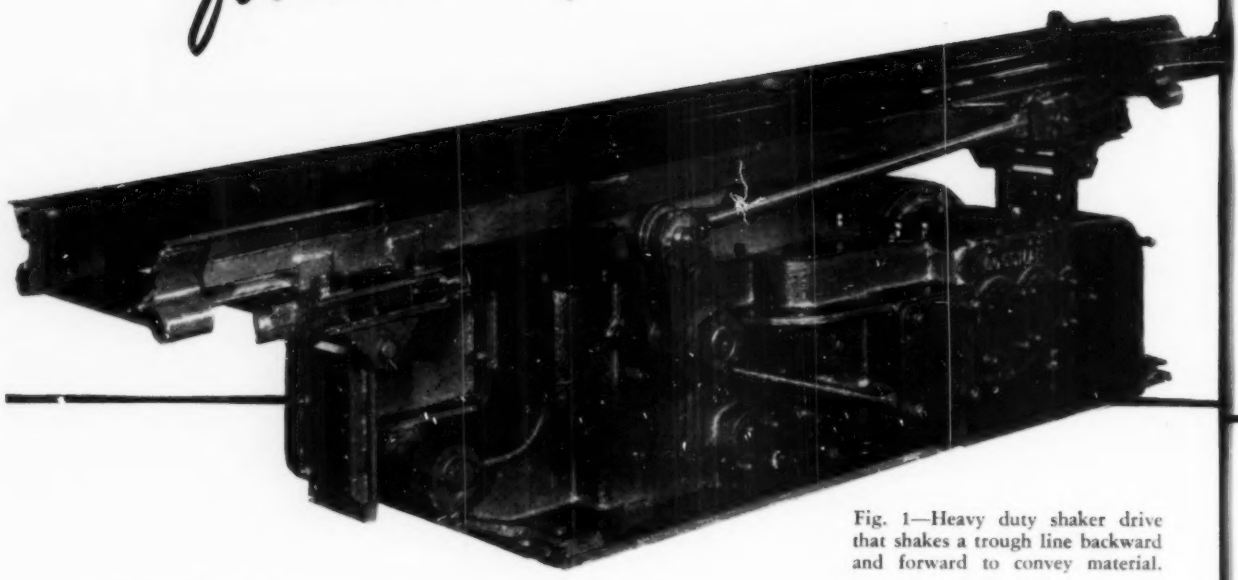


Fig. 1—Heavy duty shaker drive that shakes a trough line backward and forward to convey material.

L. D. HAGENBOOK
Chief Engineer

E. J. HLINSKY
Design Engineer
Goodman Manufacturing Company

IN THE MECHANIZATION of the mining industry, which has progressed rapidly during the last few years, much study has been given to mechanical methods for conveying aggregate materials over variable distances. For main haulage service, belt conveyors several thousand feet long have been installed. For local conveying, shaker conveyors as long as five hundred feet are in general use.

Belt conveyors are essentially moving platforms in which there is little relative motion between the conveyed material and the belt. Their design, excluding the selection of materials to be used for component parts, is chiefly concerned with power requirements, roller and bearing design, and material traction considerations.

Shaker conveyors are essentially reciprocating troughs in which the conveyed material is caused to travel by a difference in acceleration of the trough at the two ends of its stroke. For mining installation, the conveyor has attachments that permit the trough line to go around corners and to do self loading.

In the shaker conveyor system, a semi-permanently located drive unit, Fig. 1, imparts a unique reciprocating motion to an extensible trough line. Wheel or ball type units support the trough and guide it in a line parallel to its longitudinal axis. This construction is in contrast with that of early type shaker conveyors and present day vibratory conveyors, the supports of which give the trough line movement a vertical component.

The entire trough line shakes back and forth with a motion that causes the material being conveyed to slide forward a certain distance during each stroke. In the direction of material travel, the accelerating force applied to the trough is slightly less than the frictional force of the material on the trough line. In the reverse motion of the trough line, the accelerating force is as great as the resulting stresses will justify.

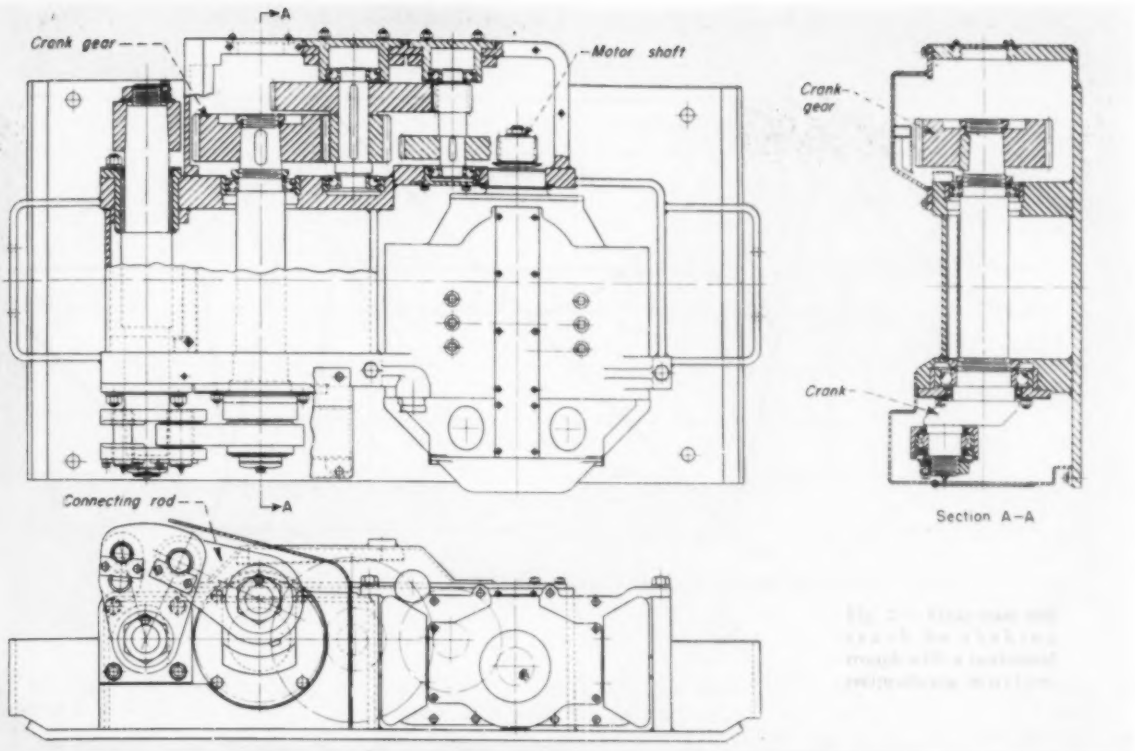
Not only is the operating space limited, but several other conditions serve to make designing difficult. First among these is poor maintenance. Miners are good machine operators and the maintenance men are good mechanics but the machine operates in a dark place and close quarters. At times the machine is miles from a repair shop. In addition, care of the machine is subordinate to the miner's first interest, which is to get out as much coal as he possibly can.

The machine must be "push-button" operated as much as is practicable. Because of the danger of coal dust or gas fires and explosions, the electrical equipment must be enclosed in strong explosion proof compartments approved by the U.S. Bureau of Mines.

In the early machines, considerable manual effort was required to turn cranks and operate levers. In modern machines, these operations are performed hydraulically.

Analysis of Shaker Motion

In an analysis of the motion of a shaker conveyor that is driven by a gear and crank train similar to that



Characteristics of motion required to convey materials in a reciprocating trough line. Acceleration, velocity and displacement produced by a gear train and crank in shaker conveyor drive units. Effect of acceleration and material friction factor on rate of material travel and backslip.

shown in Fig. 2, it is convenient to represent the motion by a velocity curve having for its ordinates the trough line velocity in feet per second plotted against time in seconds as the abscissa, or alternatively in degrees of revolution of the constant speed crank as the abscissa.

Since acceleration is the increment in velocity per increment of time, the trough line acceleration at any instant of time is a function of the slope of the velocity curve at that instant. In addition, since the increment of displacement during a time interval is the product of velocity and the time interval, the displacement of the trough line during any time interval is a function of the area under the velocity curve for that time interval.

Trough line acceleration generally is expressed as a function of the gravity acceleration unit g. The value of acceleration in the direction of material travel to convey coal is low, about the order of 0.3 g. At this value, the accelerating force is found to be less than the friction force of the coal in the trough line. On a flat polished surface a piece of coal has a low coefficient of friction, but in a full trough the coefficient of friction is about 0.4, probably because of the wedging effect along the trough sides.

Where

f = friction force, lb
F = accelerating force, lb
M = mass of material in trough
W = weight of material in trough, lb
u = coefficient of friction between material and trough surface
a = acceleration of trough, ft per sec^2
g = gravity acceleration, ft per sec^2

$f = uW$ and $F = Ma = Wa/g$

then at the instant of slippage when f equals F

$$uW = Wa/g$$

or $$a = ug$$

At about three-quarters of the forward stroke, the acceleration is reversed to cause the material to slide forward relative to the trough. In practice, the forward and reverse acceleration should bear a ratio to each other of about 1 to 3 or 4. Furthermore, the change from one to the other of these accelerations should not be too rapid, since too quick a reversal of the inertia loads may produce damaging shock on the conveyor drive and structure.

The best transition from one acceleration to the other is thought to be linear, that is, a constant rate of change in acceleration. Rates of change of acceleration of the order of 25 g to 50 g per sec, or about 800 to 1,000 ft per sec^3, are practical.

Ideal Motion Curves

Acceleration, velocity and displacement curves for ideal motion are shown in Fig. 3 for a hypothetical shaker. The assumed design requirements are 60 forward and 60 reverse strokes per min, an acceleration in the direction of material travel of 10 ft per sec^2, an acceleration opposite to material travel of 40 ft per sec^2, and an acceleration change of 1,000 ft per sec^3 during the transition from constant forward to constant reverse acceleration. The acceleration requirements are identical for both directions

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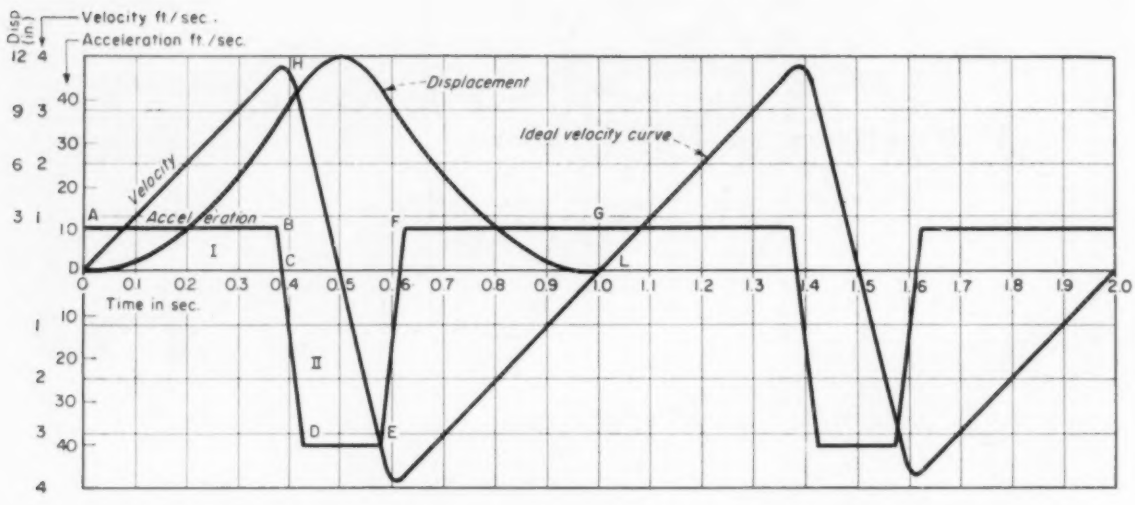


Fig. 3—Acceleration, velocity and displacement curves for ideal shaker motion.

of the motion of the trough line travel.

A symmetrical displacement curve requires that the velocity be zero at the beginning and end of each stroke, in Fig. 3 these points are at 0 sec, 0.5 sec, and 1.0 second.

Where

- t_a = time at beginning of forward stroke, sec
- t_b = time at beginning of transition in acceleration, sec
- t_c = time at which acceleration changes from forward to reverse, sec
- t_d = time at which reverse acceleration becomes constant, sec
- $t_{0.5}$ = time at end of forward stroke, sec

the diagram Fig. 3 shows that the forward velocity increases uniformly from time t_a to time t_b. From time t_b to time t_c, the forward velocity is still increasing but at a diminishing rate since the acceleration is still forward in the direction of travel.

The time interval required for the forward acceleration to change from 10 ft per sec^2 to zero at a transition rate of 1,000 ft per sec^3 is determined from

$$10 - 1{,}000\,(t_c - t_b) = 0$$

or

$$(t_c - t_b) = 10/1{,}000 = 0.01 \text{ sec} \qquad (1)$$

The time interval required for the acceleration to change from zero to 40 ft per sec^2 in the direction opposite to material travel at a transition rate of 1,000 ft per sec^3 is determined from

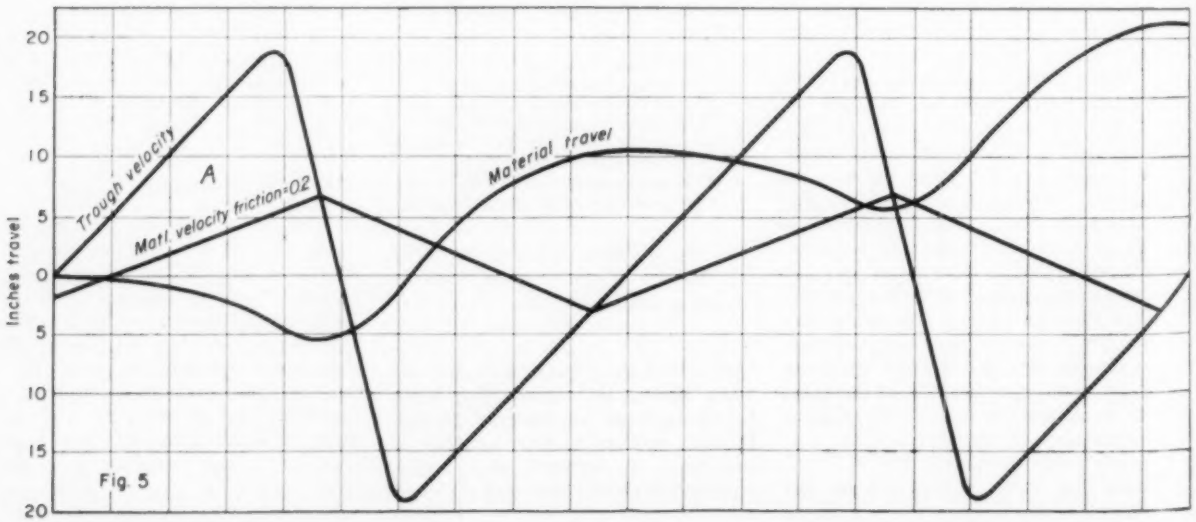
$$0 + 40 = 1{,}000\,(t_d - t_c)$$

or

$$(t_d - t_c) = 40/1{,}000 = 0.04 \text{ sec} \qquad (2)$$

In the acceleration transition period from t_c to t_d, the forward velocity decreases at an increasing rate from its maximum at t_c. From t_d to $t_{0.5}$, the forward velocity decreases uniformly to zero at the end of the forward stroke.

Since area I between the forward acceleration curve and the diagram axis is the summation of increments



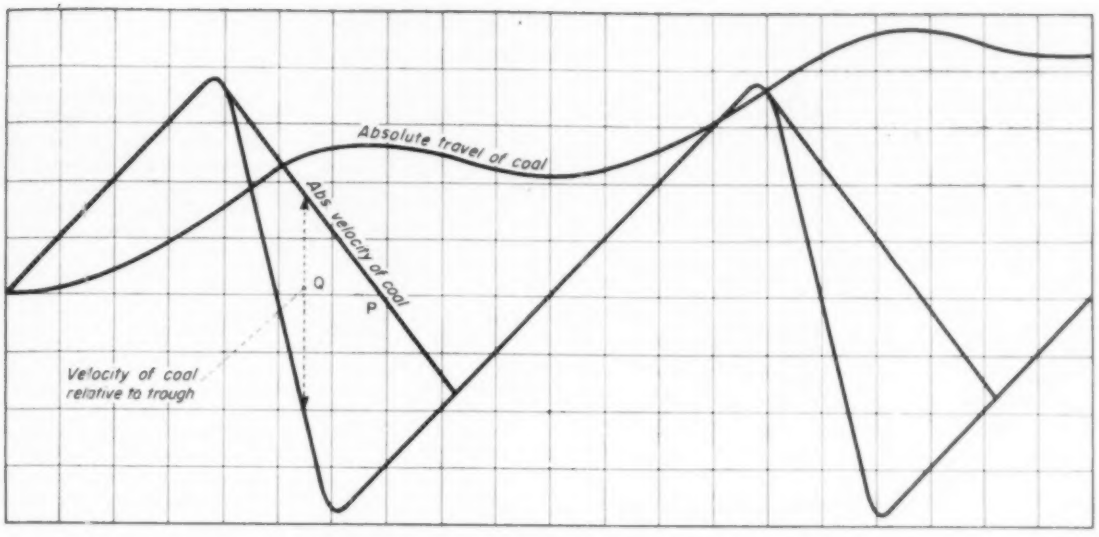


Fig. 4—Motion of coal achieved with a patented conveyor shaker motion.

of increasing velocity from zero to maximum during differential time intervals, and since area II between the reverse acceleration curve and the diagram axis is the summation of increments of decreasing velocity from maximum to zero during differential time intervals area I and area II are equal.

The specific times t_b, t_c and t_d are calculated with the aid of Eqs (1) and (2) and from the relation that areas I and II are equal, thus

$$10\,(t_c - t_a) - (10/2)\,(t_c - t_b) = 40\,(t_{0.5} - t_c) - (40/2)\,(t_d - t_c)$$

$$10\,(t_c - 0) - 5 \times 0.01 = 40\,(0.5 - t_c) - 20 \times 0.04$$

$$10\,t_c - 0.05 = 20 - 40\,t_c - 0.8$$

$$t_c = \frac{20 - 0.8 + 0.05}{50} = \frac{19.25}{50} = 0.385 \text{ sec}$$

then from Eq (1)

$$t_b = 0.385 - 0.01 = 0.375 \text{ sec}$$

and from Eq (2)

$$t_d = 0.385 + 0.04 = 0.425 \text{ sec}$$

Where

v_b = velocity at t_b, ft per sec
v_c = velocity at t_c, ft per sec
v_d = velocity at t_d, ft per sec
$v_{0.5}$ = velocity at $t_{0.5}$, ft per sec
s_b = displacement at t_b, ft
s_c = displacement at t_c, ft
s_d = displacement at t_d, ft
$s_{0.5}$ = displacement at $t_{0.5}$, ft

Then the relation that velocity at any given time is the initial velocity plus the product of constant acceleration and time, at time t_b the velocity forward is

$$v_b = 0 + 10 \times 0.375 = 3.75 \text{ ft per sec}$$

and from the relation that displacement at any given time is the sum of the initial displacement, the product of the initial velocity and time, and the product of half the constant acceleration and the square of the time, at time t_b the displacement forward is

$$s_b = 0 + 0 + (1/2) \times 10 \times 0.375^2 = 0.703125 \text{ ft}$$

likewise

$$v_c = 3.75 + (10/2) \times (0.385 - 0.375) = 3.80 \text{ ft per sec}$$

$$s_c = 0.703125 + 3.75\,(0.385 - 0.375) + (1/2)\,(10/2)\,(0.385 - 0.375)^2 = 0.740875 \text{ ft}$$

$$v_d = 3.80 + (-40/2)\,(0.425 - 0.385) = 3 \text{ ft per sec}$$

$$s_d = 0.740875 + 3.80\,(0.425 - 0.385) + (1/2)\,(-40/2)\,(0.425 - 0.385)^2 = 0.876875 \text{ ft}$$

$$v_{0.5} = 3 + (-40)\,(0.5 - 0.425) = 0$$

$$s_{0.5} = 0.876875 + 3\,(0.5 - 0.425) + (1/2)\,(-40)\,(0.5 - 0.425)^2 = 0.989375 \text{ ft}$$

The corresponding velocity and displacement curves for the acceleration specifications indicated are plotted in Fig. 3 for these calculated values. Of these three curves, the velocity curve is the most useful. Its slope at any point is a measure of the acceleration at that point, and the area under the velocity curve up to that point is a measure of the distance travelled.

The material motion curve shown in Fig. 4 is achieved with a patented

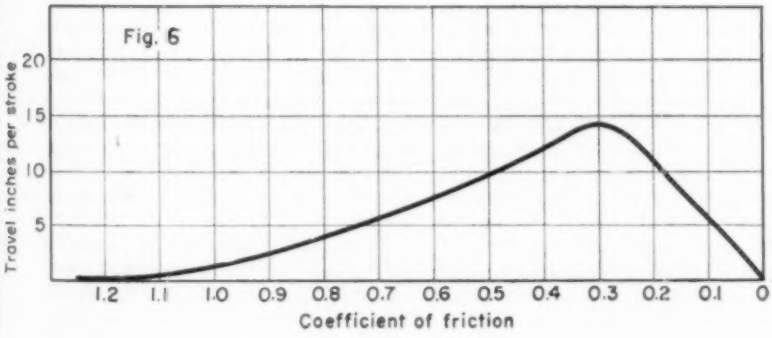


Fig. 5—Velocity and travel curves for backslip that occurs in an ideal motion when friction of material is not sufficient to hold against forward acceleration.

Fig. 6—Travel per stroke for different values of friction factor with ideal motion.

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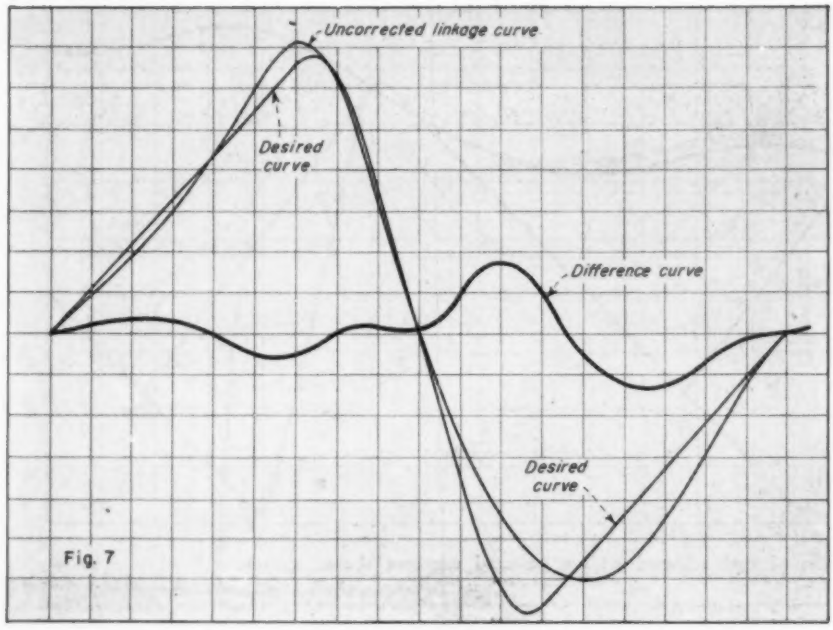
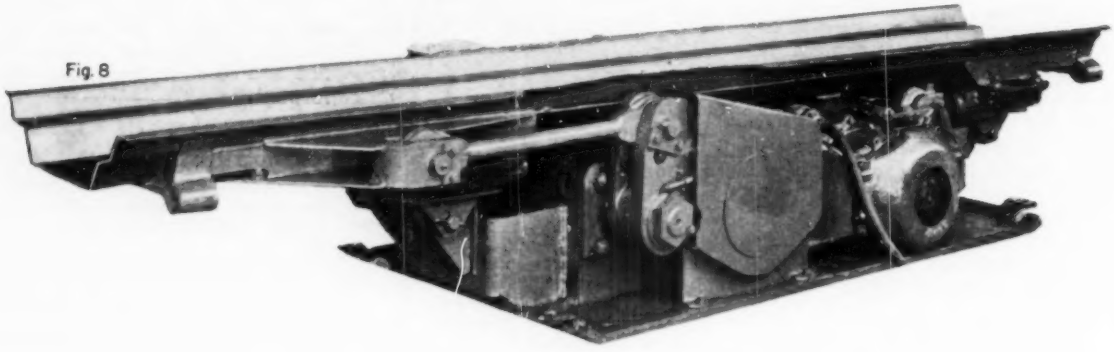


Fig. 7 — Uncorrected velocity curve as produced by a crank and short connecting rod drive compared with the ideal or desired velocity curve. The difference between these curves is a second harmonic.

Fig. 8—Shaker unit with improved drive that produces the desired ideal velocity curve. The final gear reduction for driving the crank consists of a gear having a variable tooth pitch and an eccentric pinion.



shaker conveyor motion, with it is shown the motion of coal. The effective coefficient of friction is taken at 0.4. Since this value is greater than the acceleration in g units in the direction of material travel, the material will have the identical velocity as the trough line during that part of the motion.

During the reversal of acceleration, the coal continues to ride with the trough until this acceleration reaches a value that exceeds the friction factor, at which time the coal slides. It then slides with a constantly decreasing velocity, so that the velocity is represented by a straight line on the motion curve. The slope of this line is 13 ft. per sec. by 1 sec. At point P the coal is travelling at an absolute velocity of zero feet per second, but it still has a velocity with reference to the trough so that the velocity curve of the coal continues as a straight line. This condition indicates that the absolute velocity of the coal reverses.

Note that any ordinate Q is the difference in velocity between the trough and the material, and that the area between these curves is the travel of the material with reference to the trough line. Since only the trough reciprocates, this area is also a measure of the absolute travel of the material.

If the material has a low friction factor that is not sufficient to hold against forward acceleration, back-slip occurs that quickly reduces the progress. In Fig. 5 is shown the velocity and travel curves for a back-slip condition. Not only is the positive area reduced but there is a negative area A under the gentle slope that must be subtracted.

With a theoretical velocity curve having sharp points, an acceleration in the direction of material travel exactly equal to the friction factor, and a reverse acceleration infinitely high, therefore taking zero time, the material travel will be equal to twice the stroke length. It is not possible, of course, to have such a motion. Conveyors of early design seldom have a material travel per stroke as much as one stroke length. Recent designs, however, do have a travel per stroke considerably in excess of one stroke length.

In an ideal curve such as has been discussed, the maximum travel occurs when the friction factor is equal to the forward acceleration. Any greater friction causes a decrease in travel, and less friction causes back-slip. Material travel would be zero if the friction factor was either zero or equal to the high acceleration, although neither of these is encountered in practice. In Fig. 6 the travel per stroke is plotted against several different values of friction factor. It will

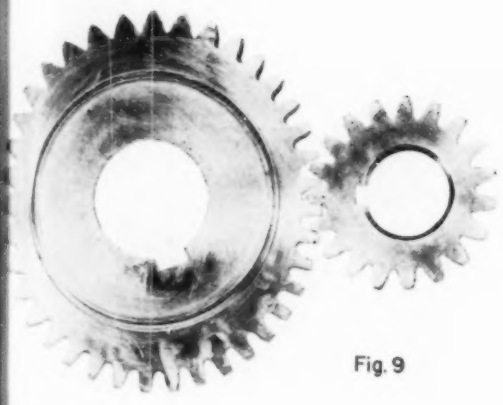


Fig. 9

Fig. 9—Variable pitch gear employed in the final reduction of gear train to obtain variable crank shaft speed and an ideal velocity curve.

Fig. 10—Trough for conveying red hot scale in which load carrying members are independent of the material carrying members. Trough sections overlap in fish scale manner.

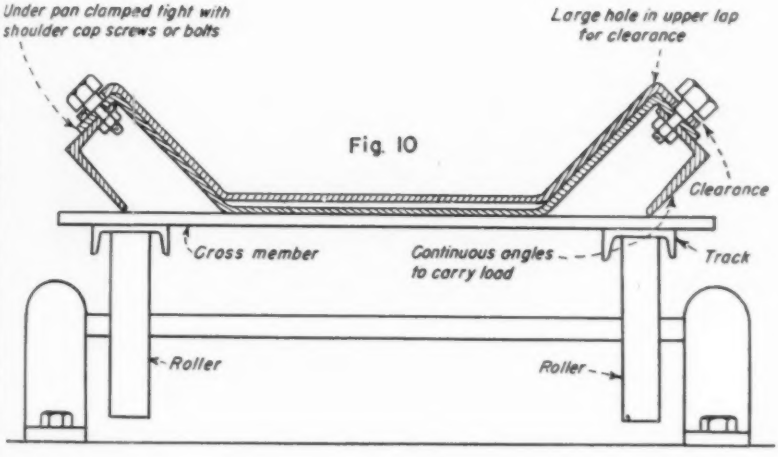


Fig. 10

be noted that friction factors of a value less than the optimum have a more adverse effect on material travel than do those that are greater.

The principal part of the motion achieved with a drive similar to that shown schematically in Fig. 2 is produced by a crank and a short connecting rod. In Fig. 7 a typical velocity curve produced by such a drive is compared with an ideal velocity curve. It will be noted that the difference between these two curves is a second harmonic.

To accommodate this difference, the final gear reduction for driving the crank was redesigned, and incorporated in the machine shown in Fig. 8, to produce the desired ideal velocity curve.

The nonuniform residual error in the forward and backward velocities was corrected by employing a gear having a continuously variable tooth pitch on the crankshaft and eccentric pinion on the large intermediate drive shaft.

The pitch "circle" of the gear is actually a smooth continuously varying pitch curve. The teeth have short addenda on certain parts of the gear and long addenda on others. No two teeth are alike. In manufacture, the gear blank is first shaped to its outside contour by a toothless disk cutter mounted eccentrically. The variable tooth pitch is obtained by mounting on the Fellows' table a false table that is caused by means of cams to have a controlled oscillation. The gear is cut on a Fellows shaper with an eccentrically mounted cutter of the exact size and shape of the pinion.

The pinion is cut in the regular manner and bored eccentrically; its teeth are standard involute and have constant circular pitch.

An ideal velocity curve is thus obtained by means of an eccentric pinion rotating at constant velocity and a non-circular gear that imparts a variable velocity to the crank shaft.

This drive is the culmination of much development work. It has proved to be better in operation and requires less horsepower per ton conveyed than any previous drive. It has a coal conveying capacity of 126 tons per hour as against 100 tons per hour of its predecessor. As a result of the reduction of peak acceleration and the elimination of harmonics, which cause destructive vibrations to travel up and down the trough line, the life of the trough line is improved.

Shaker conveyor systems are now employed to convey many hot materials such as hot castings in foundry sand, hot coke from coking ovens, red hot scale from rolling mills, and various sintered materials produced in smelting processes.

Trough for Conveying Hot Scale

A new type trough was especially developed to convey red hot scale. This trough is shown in Fig. 10 and differs from a coal carrying trough in that the load carrying members are independent of the material carrying members. On each side of the trough line the under pan or load carrying member is tightly clamped to angle irons, which stand on edge on the top surfaces of intermediate plate cross members. Short pieces of track, which run on supporting rollers, are attached to the bottom surface of the plate cross members.

The trough sections are short and semi-rigidly attached to the load carrying members to allow for thermal expansion. The trough sections overlap each other in the manner of fish scales, one end being bolted securely to the load carrying angles while the other end overlaps the succeeding trough section by a generous amount. This end is constrained to remain in this position with a predetermined latitude of freedom.

Shaker conveyors can be used to carry materials on upgrades as steep as 10 percent, and are limited on downgrades only by the tendency of the material being conveyed to run free. The carrying capacity is governed by the friction factor of the material conveyed, a good range for which is 0.2 to 0.6. The maximum length of trough line is governed by the weight of the troughing itself and to a less extent by the weight of the material conveyed.

Certain equipment items and methods of manufacture mentioned in this article are subjects of patents and patent applications owned by the Goodman Manufacturing Company.

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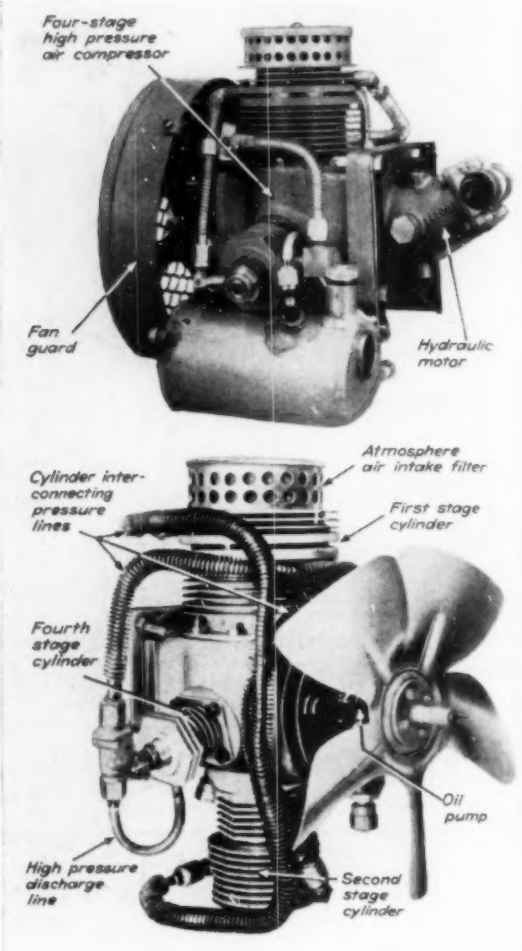
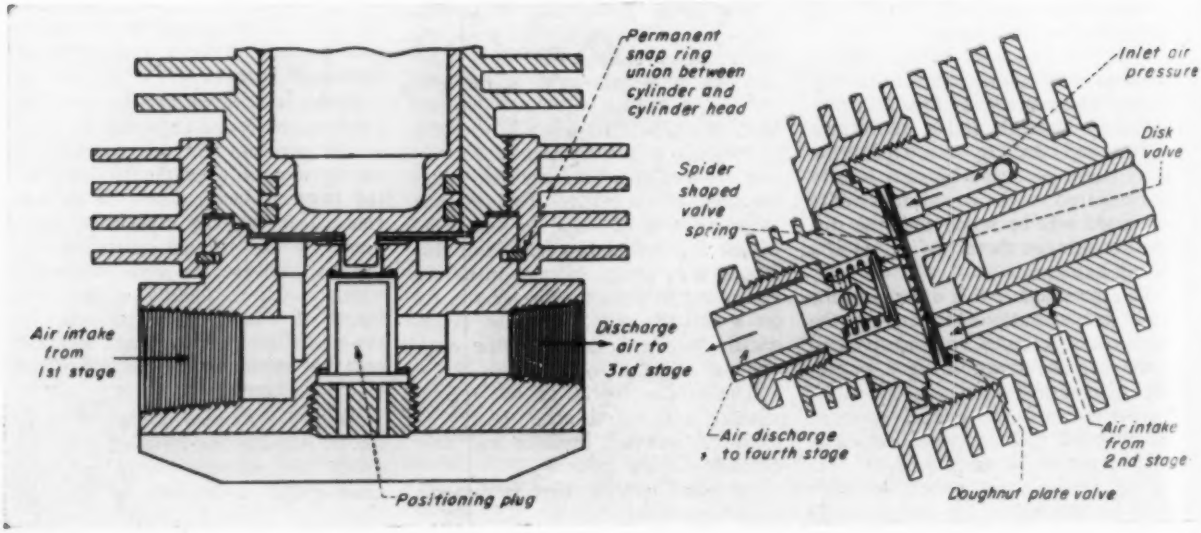
High Pressure Compressor Pistons Driven by "Keystone"

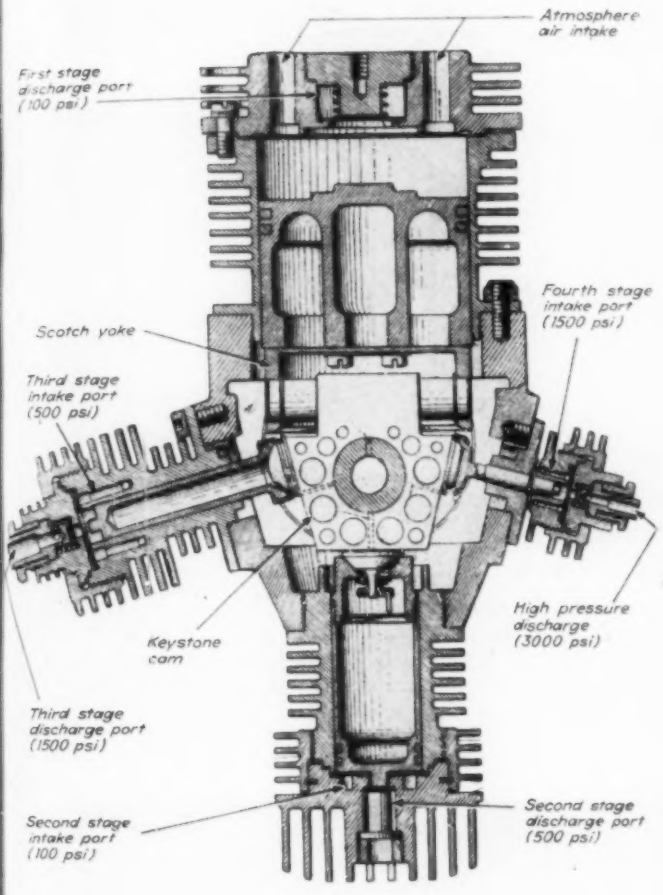
A four stage, four piston, high pressure air compressor, developed by Walter Kidde and Company, Inc., uses a method of driving the pistons that eliminates the need for connecting rods, wrist pins and other complications inherent in conventional compressor design. The heart of the method is a Keystone shaped cam that rides in an upright position on the crankshaft and pushes the pistons into their cylinders with its flat sides as it oscillates.

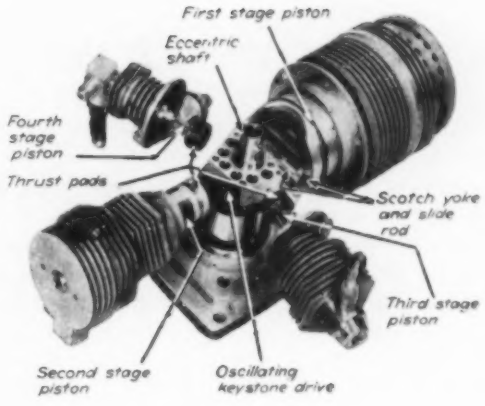
Through the use of this piston drive the weight of the new compressor has been held to 15 lb yet it will deliver 4 cfm free air at 3,000 psi pressure. The compressor has been designed for aircraft use and this output is believed sufficient to meet the requirements that exist today.

Other interesting design features include the pressure lubricating system, a unique valving and porting arrangement and the method by which the piston pads are kept aligned with the sides of the Keystone cam. Three separate methods are used to attach the cylinders to the cylinder heads and on the second stage cylinder assembly a snap ring permanently holds the cylinder head to its threaded union adaptor.



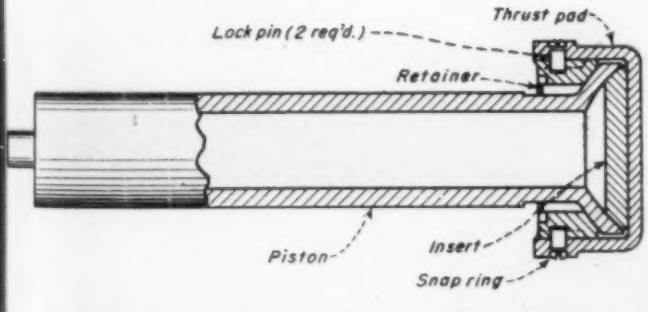

Permanent snap ring union between cylinder and cylinder head
Inlet air pressure
Disk valve
Spider shaped valve spring
Air intake from 1st stage
Discharge air to 3rd stage
Air discharge to fourth stage
Air intake from 2nd stage
Positioning plug
Doughnut plate valve


Atmosphere air intake
First stage discharge port (100 psi)
Fourth stage intake port (1500 psi)
Scotch yoke
Third stage intake port (500 psi)
High pressure discharge (3000 psi)
Keystone cam
Third stage discharge port (1500 psi)
Second stage intake port (100 psi)
Second stage discharge port (500 psi)



KEYSTONE CAM with pistons and cylinders arranged in their proper relative position. The Keystone rides on the crank and its flat sides push the pistons into the cylinders. During the intake strokes the pistons are kept in contact with the cam by live air from the preceding stage. As the crank shaft rotates, the Keystone is held upright and oscillates on the slide rod of a yoke fastened to the first stage piston.

ANNULAR GROOVES in the cylinders or in the cylinder heads form inlet ports, and the air discharge ports are in the cylinder heads. Oil is pumped in through the hollow crankshaft and passages in the Keystone cam to the thrust pad surfaces.



BALL SOCKET permits the thrust pad to align itself and ride flat on the Keystone cam. Slight variations in cam position can result from part dimension tolerances.

SECOND STAGE CYLINDER adaptor and cylinder head are permanently assembled by a snap ring. A positioning plug holds the discharge disk valve in position without restricting its movement or interfering with air flow through the ports.

THIRD STAGE VALVE arrangement is typical of all valving in the compressor. Spring loaded check valves are used in all but the second stage. The inlet valves are doughnut shaped disks and the discharge valves are solid.

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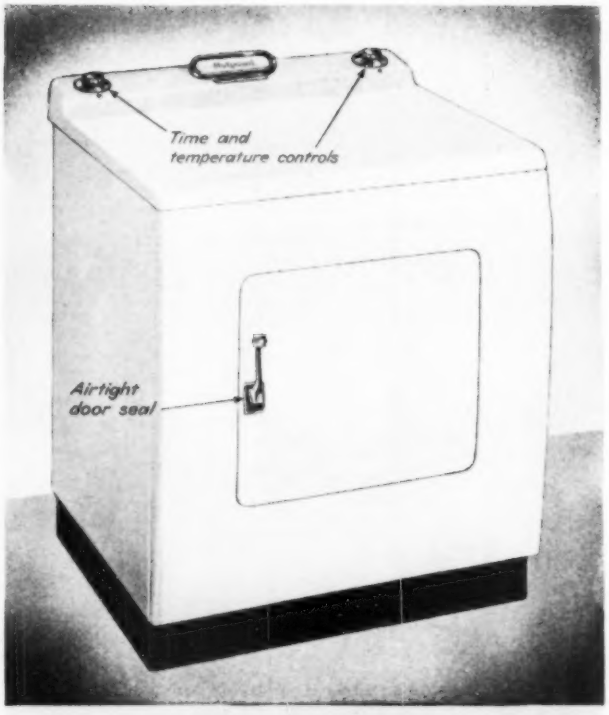
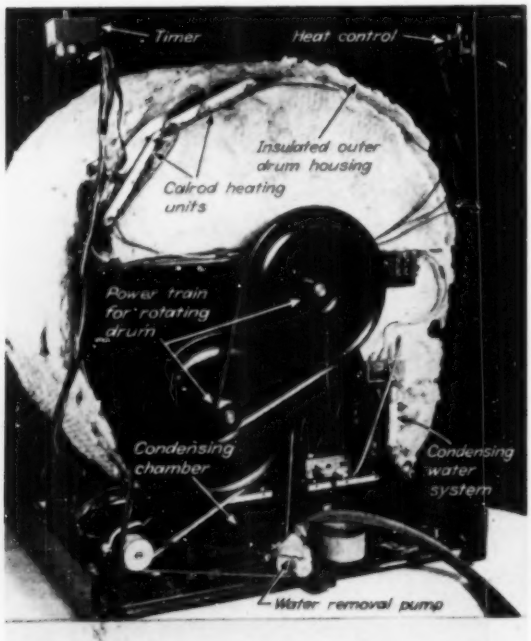
Water Condenser For Clothes Dryer

On the surface, it seems a paradox that water should be used to improve operation of an automatic clothes dryer, but a unit being manufactured by Hotpoint, Inc. successfully uses this method. The clothes to be dried are placed in a conventional type perforated revolving drum that is encased in a sealed housing to prevent air from entering or escaping when the dryer is in operation. In addition to the usual dryer mechanism, a water system has been added in a confined area under the drum called the condensing chamber. A stream of water enters the condensing chamber and is mechanically atomized to fill the entire chamber.

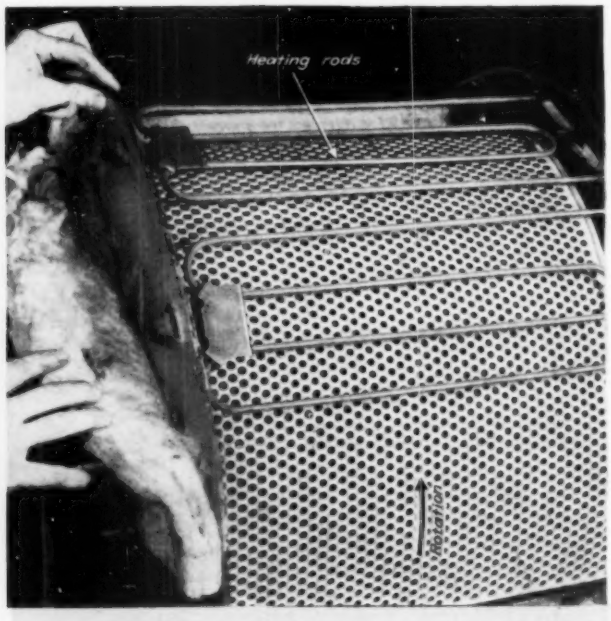
As the dryer revolves, it circulates the moisture-filled air round the closed chamber and over Calrod heating rods where baffles direct it into the drum full of wet clothes. With its capacity to hold water thus increased, the heated air passes through the clothes, taking on water to its saturation point on way. When it reaches the condensing chamber, the saturated air is chilled and the vaporized water condenses and is pumped out the drain.



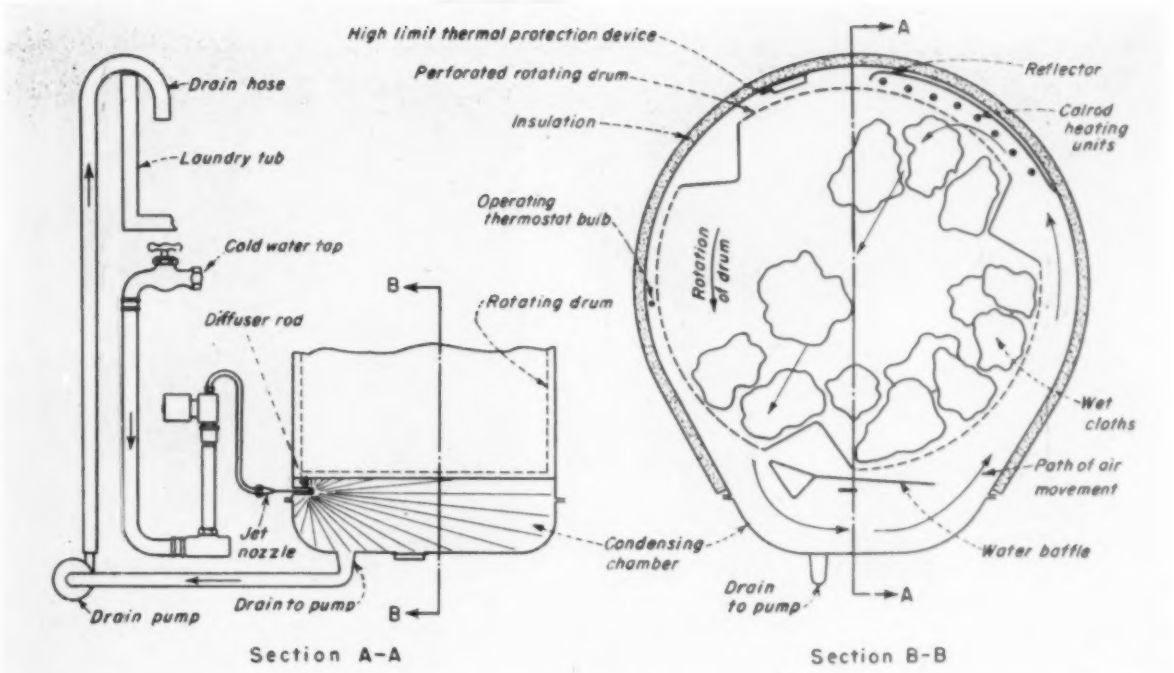
WATER SPRAY condensing chamber speeds the operation of this clothes dryer, which has a capacity of 8 pounds of dry clothes. The cabinet is sealed during the drying operation and water removed from the clothes is pumped out in liquid form.



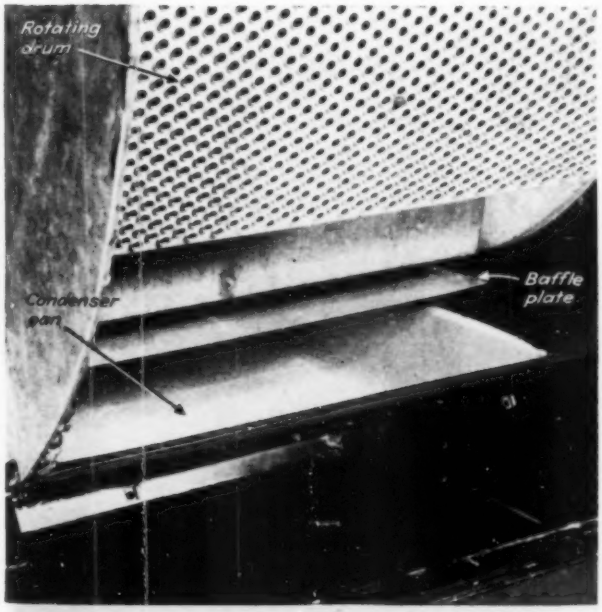
INSULATED outer drum housing encloses the rotating drum and condensing chamber. The timer coordinates the motor with the water jet.



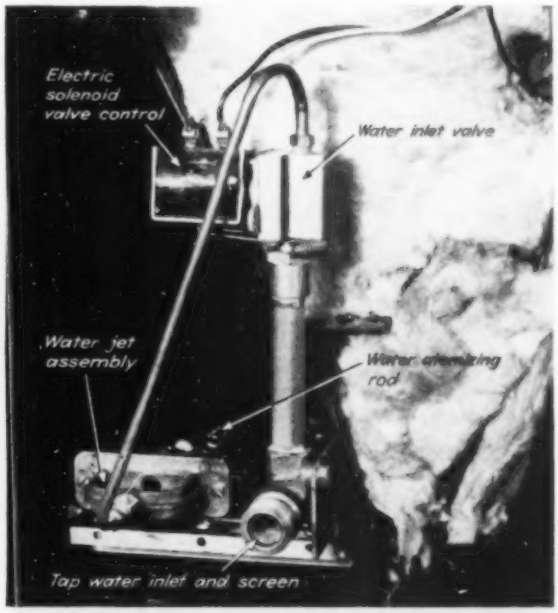
WITH SECTION of outer drum removed, the rotating drum is exposed. Here are shown the rods that heat the air before it is directed through the clothes.



TAP WATER enters the condensing chamber and is atomized and diffused when it leaves jet nozzle and strikes a small steel cylindrical bar. The perforated rotating drum acts as a pump and forces the saturated air around the chamber to the heating rods. With its saturation temperature increased by heat, the air is directed through the perforated rotating drum where it is resaturated. As the air passes into the water spray of the condensing chamber, the moisture in suspension condenses.



BOTTOM SECTION of dryer with cover removed shows condenser pan and the baffle plate. A pump under the condenser pan removes the excess water.



CONDENSING WATER inlet system closeup shows the rod where the water strikes with sufficient force to be diffused.

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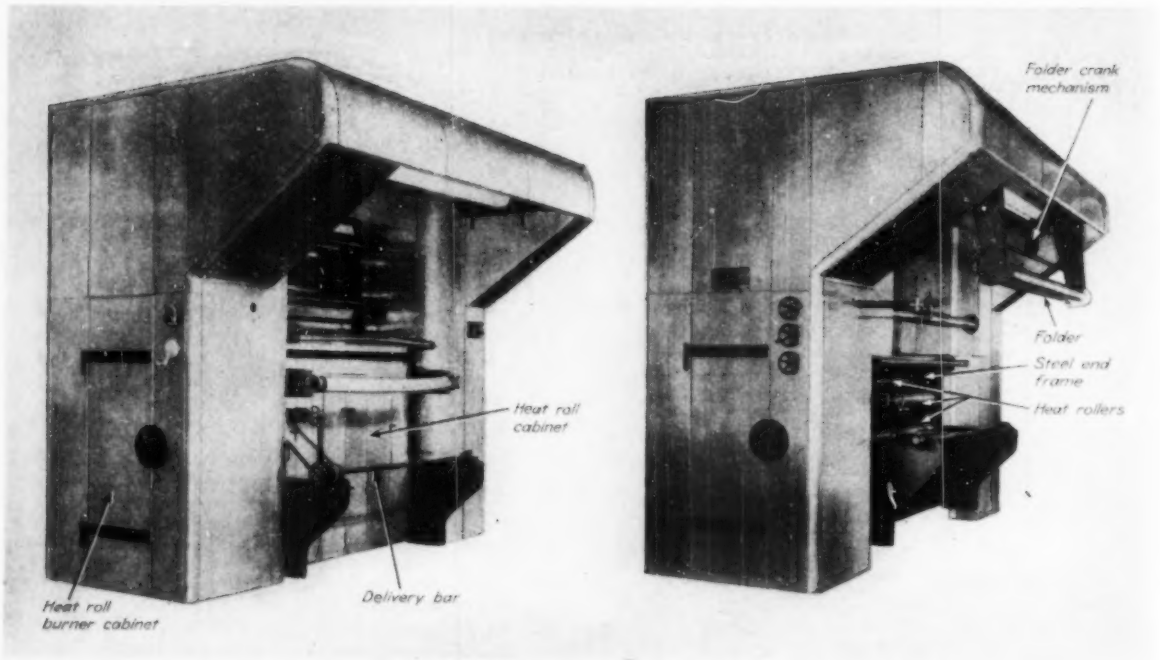


DELIVERY END of nylon heat setting machine. First the nylon fabric passes over a series of uniformly heated rolls to heat set the fabric, and then it is cooled by a controlled air blast. Functional parts are enclosed in an aluminum cabinet with access doors for normal service and adjustment.

SIX ROLLERS heat the fabric. Each roller consists of a 10 in. outer shell and an 8 in. inner shell mounted concentrically and sealed at the ends to form a cylindrical casing. This hollow casing is filled with "Dowtherm," a chemical with an extremely high boiling point.

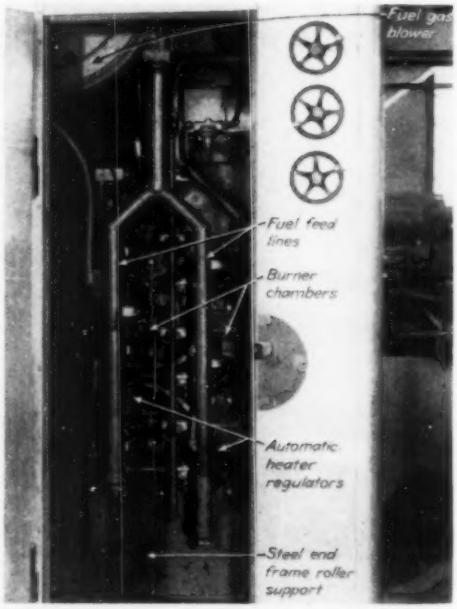
Operations Combined in the New

Heat setting and quick cooling operations in the making of nylon fabrics have been combined into one continuous process by a machine being produced at the National Drying Machinery Co. of Philadelphia.

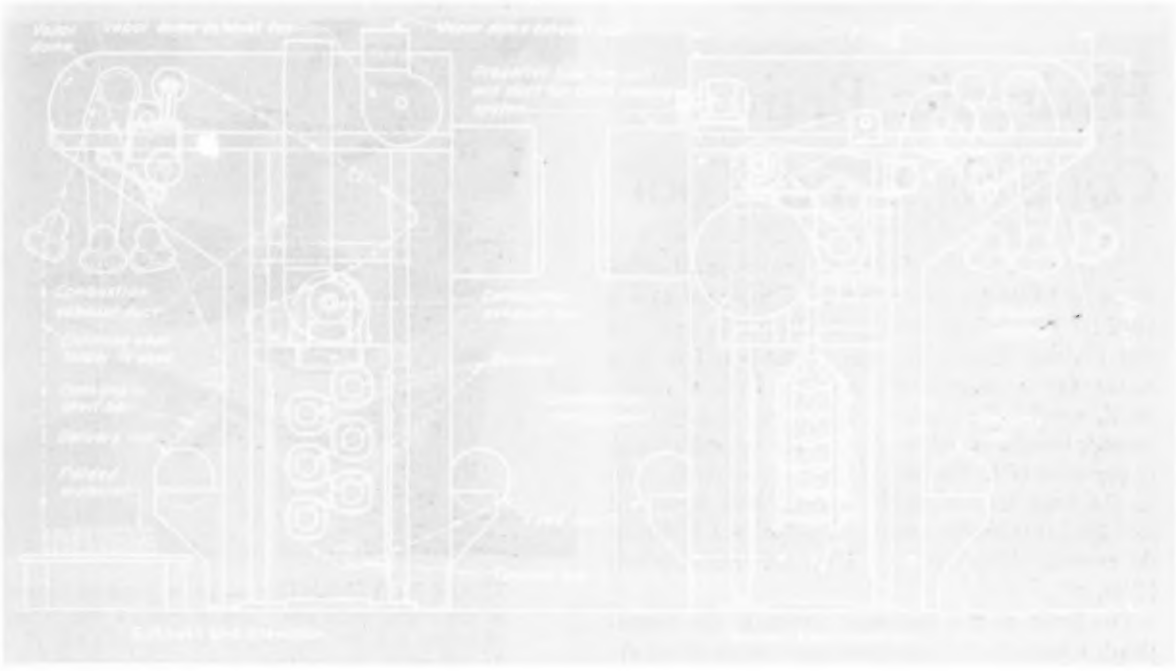
This nylon heat setting machine is equipped with six individual gas-fired rolls for heating the nylon fabric, and an air blast device that directs cooling air on the fabric after it has been set and before it is beamed or folded.

Each gas burner is automatically controlled and adjustable to any temperature required up to 500 F. Safety controls are used throughout. With a roll surface temperature of 420 F, an average of 85 cu ft of propane gas at approximately 2,500 btu per cu ft is required.

The maximum width of cloth that can be handled is 66 in., since the face width of the rolls is 72 inches. The machine weighs 12,000 lb. The machine is equipped with a manually operated U. S. Vari-drive Speed Control Unit. This variable speed reducer unit drives the cylinders and permits production speeds from 12 yards per minute to 90 yards per minute. With this range of attainable speeds, any weight of nylon fabric can be properly heat set at the highest and most efficient speed without danger of fusing due to overexposure. Five motors, ranging from 1½ hp to 3 hp are used separately to drive the fans and feed roller belt.



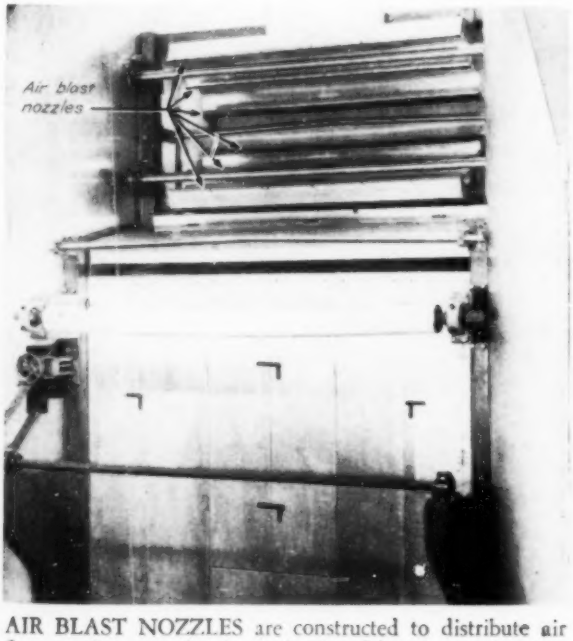
EACH CYLINDER is supplied with an individual and automatically controlled gas burner. Heat can be controlled to ±2 F.



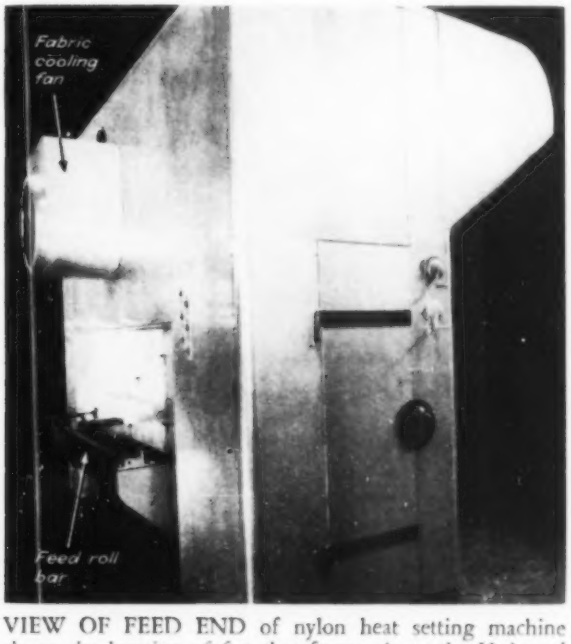
PATH NYLON FABRIC follows as it passes through the heat setting machine is indicated by dotted lines and arrows on exhaust (right) side elevation. The finished material can be beamed directly from the cooling section or passed through the crank actuated folder attachment.

DOTTED LINE and arrows on burner (left) and elevation show electric motor and belt power train that pull material through heat setter. A 2 hp (3600 rpm) motor furnishes power for the main cooling fan, and three 1½ hp fans cool the rollers and exhaust the burned gases.

Nylon Heat Setting Machine



AIR BLAST NOZZLES are constructed to distribute air flow evenly across the sheet of nylon fabric to set plastic in weave. Bars guide the fabric past the nozzles.



VIEW OF FEED END of nylon heat setting machine shows the location of fan that forces air to the V-shaped nozzles for cooling the fabric being processed.

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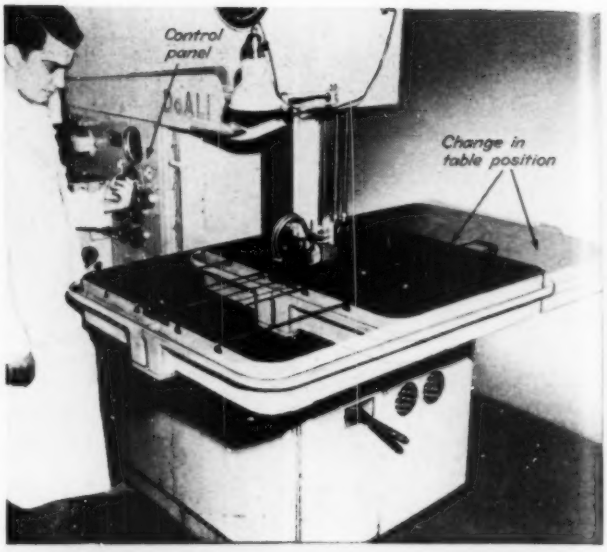
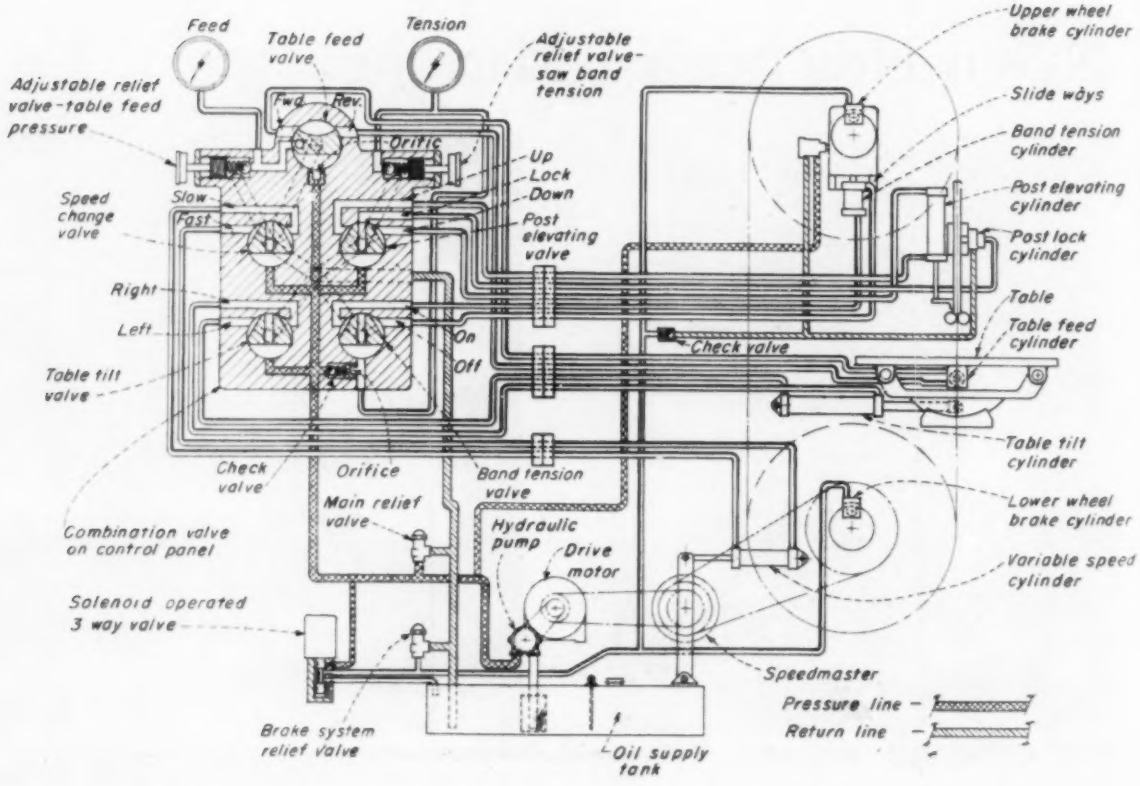
Hydraulic Brain Controls Band Tool

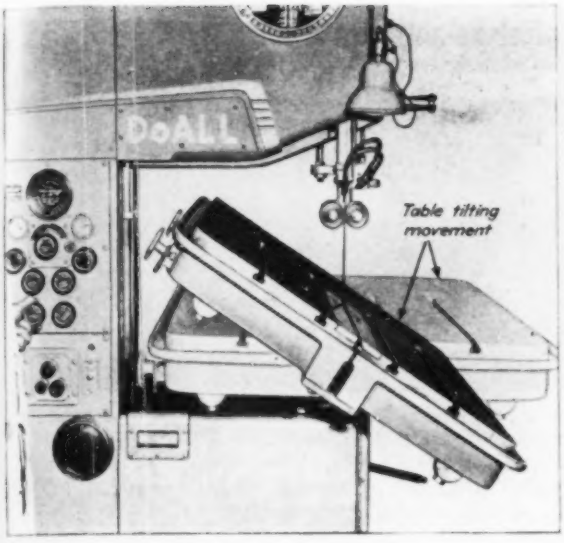
To permit infinitely variable adjustment in all movements, a hydraulic system has been designed into a band machine being made by the DoAll Company of Des Plaines, Illinois. Hydraulic cylinders, fed by a motor driven pump and controlled from a central panel, control the tension of the band tool and the speed it travels, as well as the positioning and moving of the work table. One of the most important features on the band machine is the hydraulically controlled tool head that can be remotely manipulated to follow the contour of the work as it is carried across the tool blade.

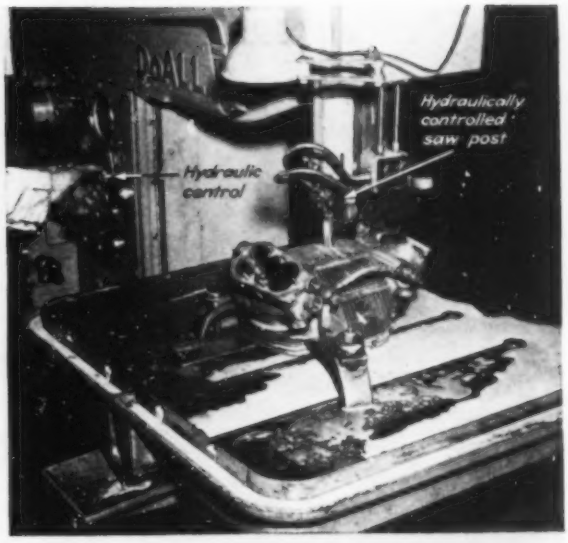
The brain of this hydraulic system is the control panel, where specially designed gate valves direct the oil to the various actuating cylinders and where relief valves determine the pressures to be exerted.



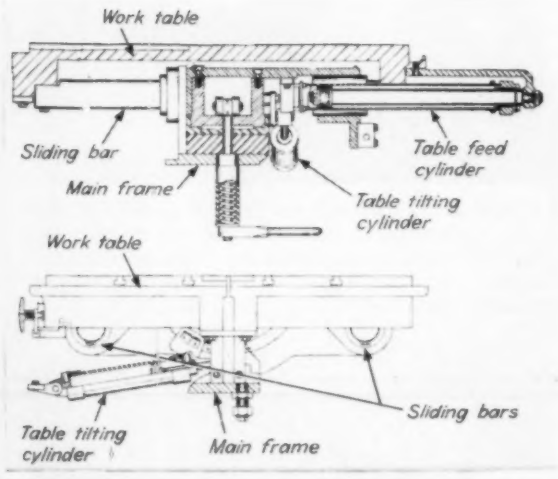
THREE MOVEMENTS that can be remotely controlled on the DoAll band tool. The table has a feed stroke of 16 inches and can be tilted to 45 deg right and 10 left. An actuating cylinder that is vertically mounted to the

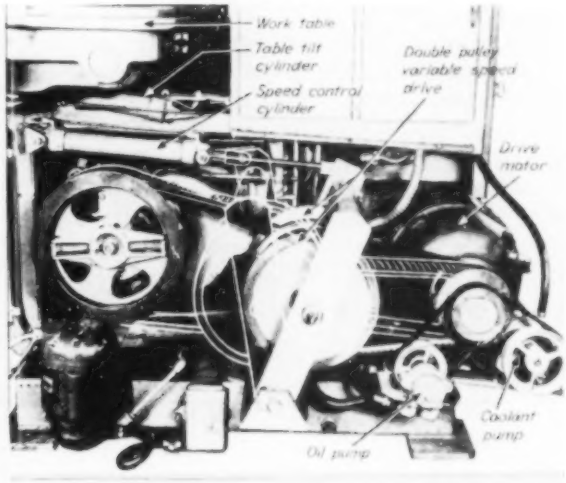






tool post can be regulated to guide the post along the vertical contour of the work that is being passed through the saw blade. When the tool post is not being moved, a hydraulic post lock cylinder automatically locks it in place. Hydraulic controls regulate the speed of the band tool blade and hydraulically actuated brakes protect the operator from possible injury by automatically stopping the machine if a cutting blade breaks.





WORK TABLE actuating cylinders. The table feed cylinder moves the tables over the tilting assembly on two sliding bars while the tilt assembly remains in the same position. The table trunnion rocks in a crescent-shaped cradle, on the main frame.

SCHEMATIC LAYOUT of the hydraulic system. The special gate valves in the control panel direct the oil from the pump to the hydraulic cylinders and adjustable spring loaded relief valves control the pressure that is exerted to the band tension and table feed actuating cylinders. Note the automatic emergency brake circuit.

POWER TO DRIVE the band tool comes from a 7½ hp electric motor through a double expanding pulley variable speed drive. The position of the expanding pulleys is determined by an actuating cylinder that is connected to the bracket in which the pulleys are mounted. Extra V-belt drives from the motor, drive the oil pump and the coolant pump. By means of this hydraulically controlled pulley drive in conjunction with a three speed transmission, blade surface speed is infinitely adjustable from 40 to 10,000 feet per minute. Speed is regulated and registered at the panel.

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Clickless Combination Lock

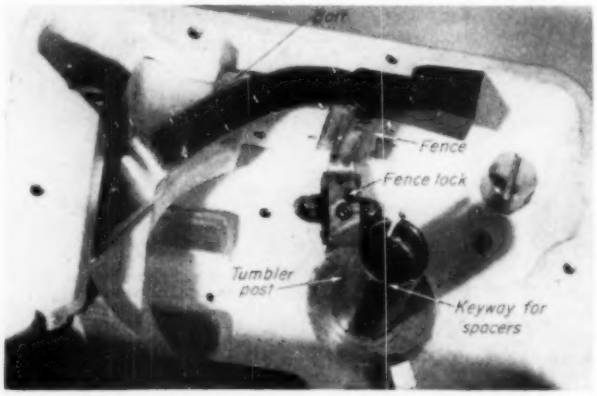
A method for mechanically positioning the gates of a combination safe lock keeps the fence or bolt pull from touching any moving part until the lock is ready to open. This lock developed by Mr. Anthony Papini of Ridgefield, N. J. is claimed to be pick proof. Safe locks made with this principle are different from conventional locks where the fence rides directly on the cam periphery and produces a give-a-way click whenever a gate passes.

This new method, employs a light spring load latch that holds the fence away from the rotating tumblers until all their gates are correctly aligned, and includes means for releasing the latch when these conditions have been met.

On the face of each tumbler and near its gate is a small semi-spherical projection. When the gates are being aligned in the unlocking process these projections are also being aligned and are increasing the distance across the plates until finally they displace the latch and release the fence. Adjustments are provided to insure that the fence will drop at the point of maximum distance across the pile of tumblers.

Each tumbler is made of two concentric disks. The outer plate contains the gate and fits around the inner plate which rides on the tumbler post and carries the key and keyway. By repositioning the plates, the combination is changed.

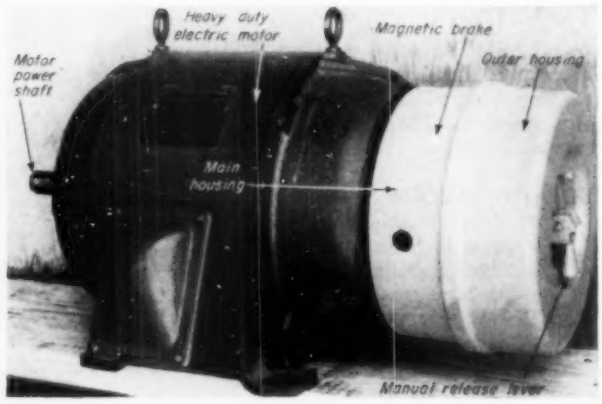
DIAL of a combination lock is directly connected to the cam by the cam shaft. As the dial is rotated, a pin type key on each tumbler engages a keyway in the tumbler of the next higher order. If the dial is turned as many times as lock has tumblers, all tumblers will be engaged.

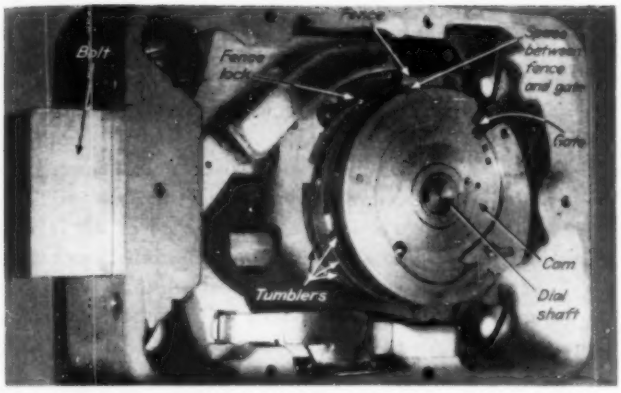


FENCE LOCK as engaged with the fence is shown with the cam and tumblers removed. Adjustment screws are provided to give the lock variations in sensitivity. Flat disk spacers, loosely keyed to the tumbler post, separate the tumblers and prevent miscellaneous displacement by friction.

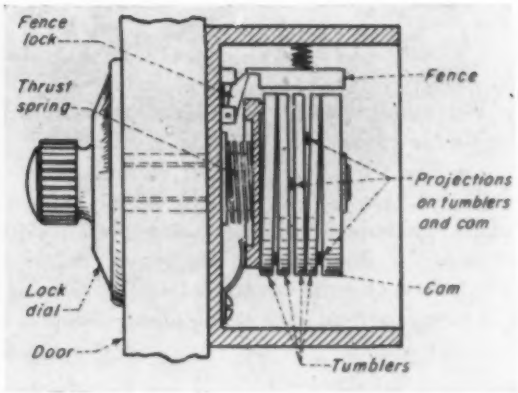
Magnetically Operated Disk Brake for Electric Motors

Used for stopping the free rotation or coasting of heavy duty electric motors or other rotating machinery, this spring actuated magnetically released disk brake has a housing designed to permit adjustment of stopping torque and disk clearance without dangerously exposing any of the rotating parts. Made by Dings Brakes Inc. of Milwaukee, Wisconsin, the brake will fit on NEMA Type C flanges and can be connected to line leads of either 220 or 440 volts motors without changing the coils of the electro-magnet actuator.

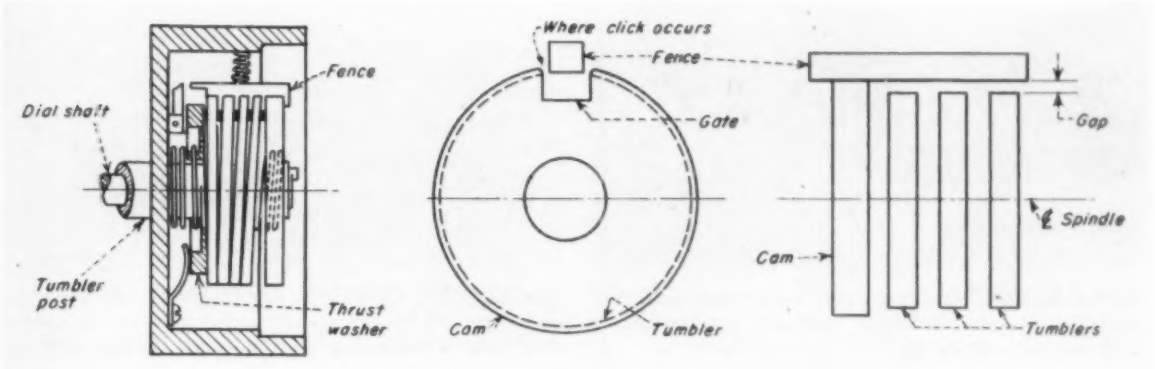




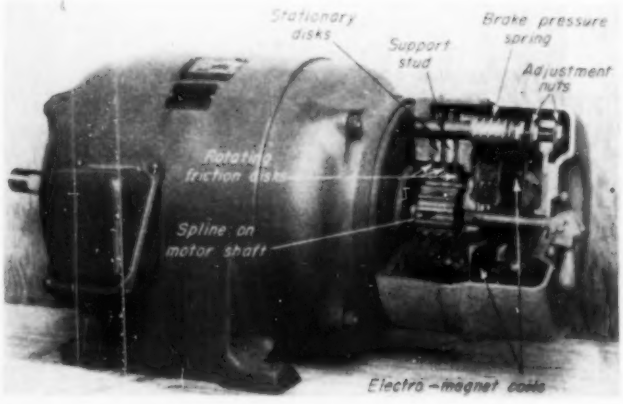
REAR OF CLICKLESS combination lock with cover removed. By reversing the direction and turning dial to predetermined positions, each tumbler can be stopped when its gate is opposite the fence. When all the gates are aligned the fence lock releases the fence which engages the cam and the lock can be opened.



FENCE LOCK is engaged in holding the fence away from the cam and tumblers. Each tumbler and cam carries a small semi-spherical projection which rides on spacers (not shown) on its forward side at its gate and a thrust washer keeps all the tumblers in contact.



CAM IS KEYED to the dial shaft but the tumblers ride loosely and are free to tilt on the tumbler post. When the gates on the tumblers have been aligned ready to receive the fence, the semi-spherical projections become aligned, increase the distance across the pile of tumblers, and tilt the thrust washer which releases the fence latch. The fence drops into the gates and the lock is ready to be opened. In conventional combination locks, the fence rides on the cam and tumblers. When the cam is turned an audible click is produced as the gate passes the fence.



HOUSING OF THE BRAKE is made in two mating bell shaped sections. The cast iron main section bolts to the electric motor, serves as a mounting bracket for the two main support brake studs and encloses all the rotating parts. The outer section is held in place by four screws and covers the electro-magnet assembly, the actuating springs and the adjustment nuts. By taking out the four holding screws, this section of the housing can be removed and the adjustment nuts exposed. It is made of cast aluminum to minimize over-hang weight. The rotating friction disks are molded asbestos and the stationary disks are cast iron. Two symmetrically mounted magnets supply the forces to compress the springs and release the brake. A cam type release lever permits manual release of the brake in case of powder failure.

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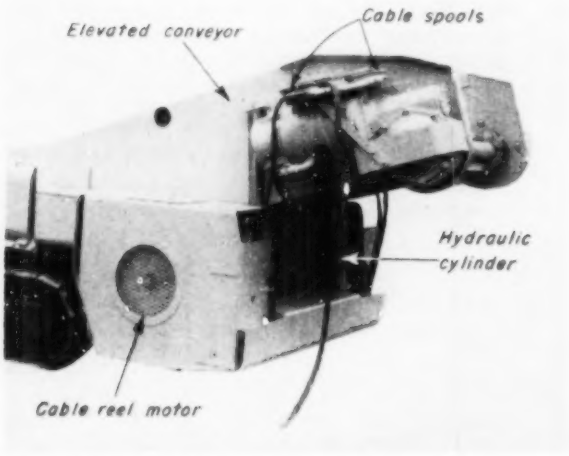
Shuttle Car With Hydraulic Controls

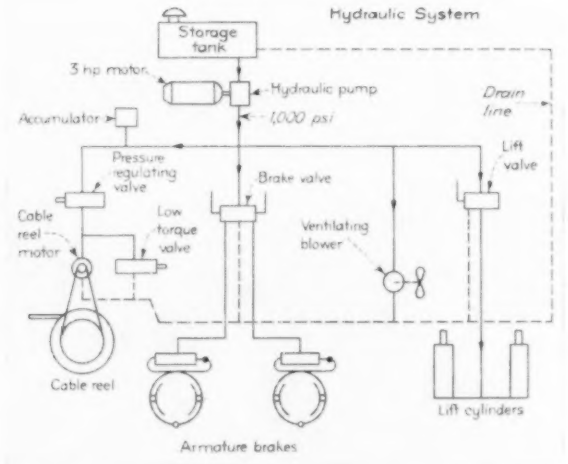
Coal miners consider maneuverability and capacity the two most important characteristics desired in the conveyor type shuttle cars they use to transport raw coal from the coal face to the secondary heading of the mines. In conventional wheel driven cars the steering linkage and wheel turning angles limit the extent to which these qualities can be exploited.

The crawler type track laying carriage adopted by the Locomotive and Car Equipment Department of General Electric Company for their new shuttle car, eliminates the need for wheel turning clearance and permits the use of a wider conveyor belt, thus increasing capacity.

Hydraulic controls have been applied to the crawler design and remove the need for complicated mechanical steering linkages as found on wheel cars. With one track locked, the car will turn in a 14 to 16 ft radius.



TRACK LAYING shuttle car, exerts a ground pressure of 15 lb per sq in. fully loaded. The cars are available in three sizes with capacities of 140 cu ft to 535 cu ft.



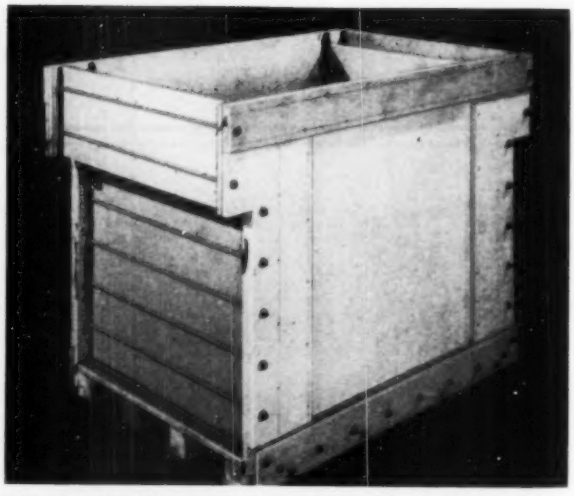
HYDRAULIC CONTROL CIRCUIT. The electric circuit is broken and hydraulic pressure is applied to the steering brake on the motor by advancing the brake valve lever.

Plywood Plating Tank

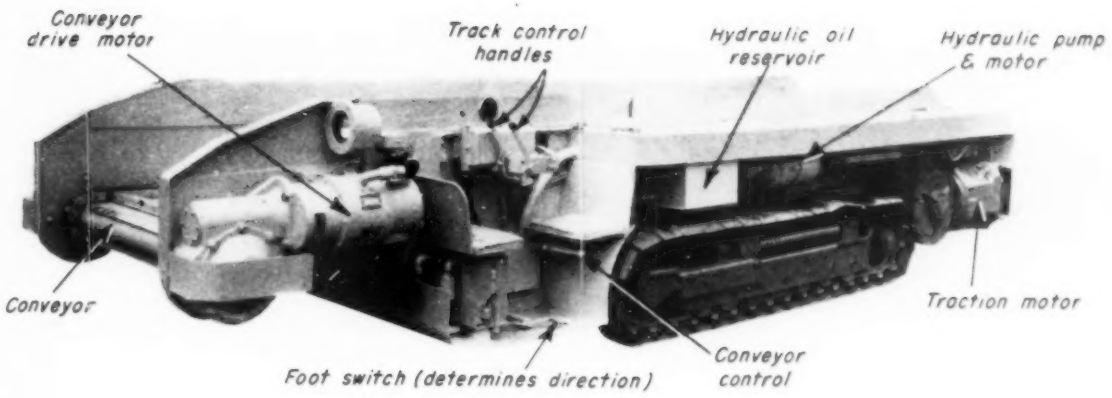
Plywood is being successfully used as the material in tanks for electrolytic baths of ferrous chloride with a ph factor of about 0.05. The material is high-density plastic surfaced Douglas fir plywood made by several plywood manufacturers.

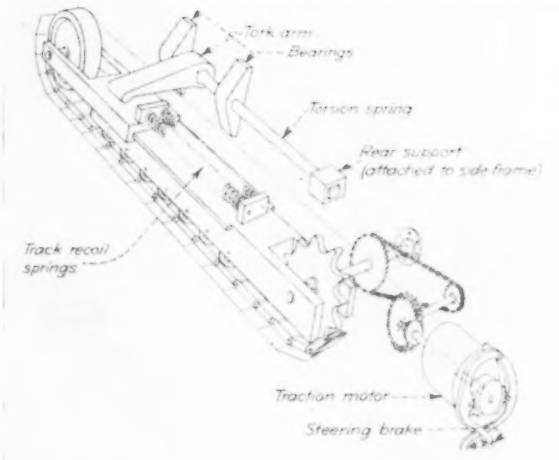
When fabrication of a plywood tank is finished it is sprayed with 6 coats of phenol-vinyl paint. Damage to the inside of the tank can easily be repaired by either repainting or replacing the damaged part. The cost of a plywood tank is said to be 15 to 20 per cent the cost of an equivalent steel tank.

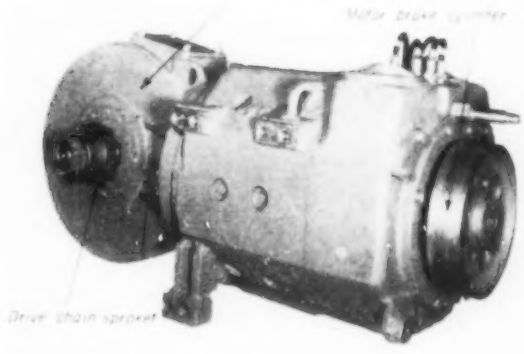
Because plywood doesn't split, filters can be made from panels half the thickness of solid lumber, doubling the capacity of the filter rack. The filter material is nylon cloth and is claimed to last at least two years when filtering common industrial solutions.



PLYWOOD TANK above is 3 ft wide, 5 ft long, 4 ft deep and has a 350 gal capacity. The end sections are mortised into the sides and all joints are sealed with a MMM rubberized compound.

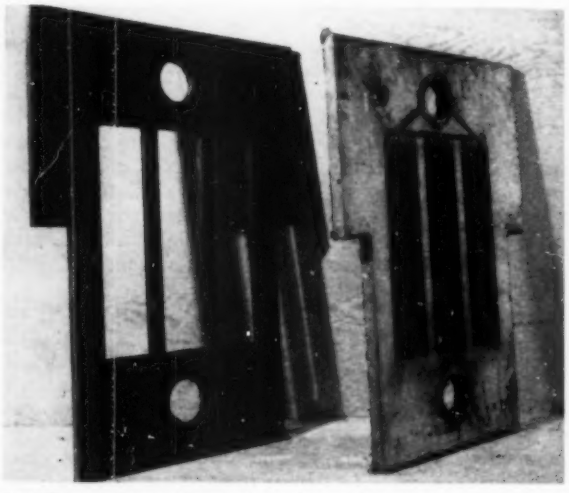






THE TRACK CARRIAGE is hinged to the body at the track drive end, and is flexibly connected to the body on the front end by means of a bar type torsion spring.

ONE 250 volt, 20 hp series wound motor drives each track through single gear reduction, chain and sprocket. The reduction gear case is an integral part of the motor.



FILTER AND OVERLAY of standard Douglas fir plywood treated with phenolvinyl paint. The plywood is said to outlast the solid wood but both materials maintain good acid resistant qualities after treatment.

SPRAYING TANK COMPONENTS with phenolvinyl paint. The thinness of plywood, as compared with stand lumber, doubles the capacity of filter racks. Ease of fabrication keeps the cost of the plywood tanks low.

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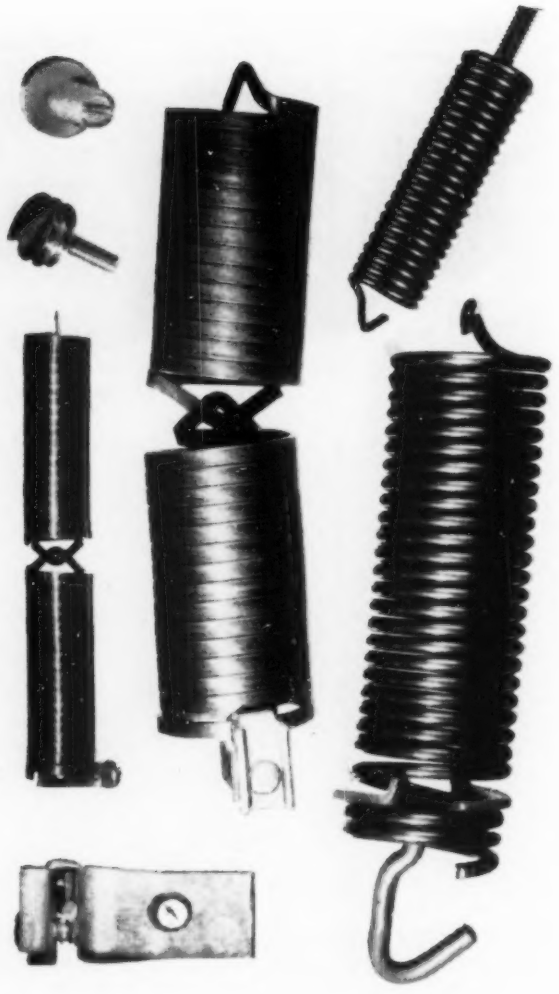
Designing Springs For Precision Measurement

M. G. FANGEMANN
John Chatillon & Sons



In addition to the physical factors that govern the reactions of spring materials to varying service conditions, there are other design factors such as coil construction, calibrator design and space considerations.

THE PROPER CHOICE of springs and spring materials for use in instruments, computing scales and other precision measuring devices determines to a large extent their overall accuracy of indication. In addition, the conditions under which these devices operate vary considerably, so that several factors other than those that influence accuracy should be considered in designing the required springs. These factors include compensation for temperature changes, design of calibrators, provision for simplicity of calibrator adjustment and allowance of sufficient space for operation as well as installation of a spring.

Sources of Error

Drift. The physical and mechanical properties of spring materials have an important bearing on spring accuracy. A peculiar property of spring materials is one generally known as "creep." Whenever a spring is loaded for an appreciable length of time, it undergoes two different types of deformation simultaneously. The spring appears to deflect immediately with the application of load and reach stability. But if accurate measurements are made, it will be found that a second or delayed deflection or "creep" takes place. This movement may continue for minutes, hours or even days, depending on the fiber stress of the spring material or on the work hardening taking place.

In recent years, the term "creep," as it exists at normal temperatures, has come to be known as "drift." Fig. 1 is a diagrammatic representation of this term. The meaning of "creep" has therefore been modified to apply specifically to plastic flow at elevated temperatures.

A steel spring normally has a "drift" error of approximately 0.02 percent of deflection after one hour of continuous loading, and about 0.065 percent after 24 hours. If the same spring is made of special alloy such as Iso Elastic, the total error can be reduced to approximately 0.01 percent in 24 hr of continuous loading.

For temperature compensated precision weighing scales, the National Bureau of Standards specifies in Table 6 of Handbook H-44 that 30-lb computing scales must not have more than 0.065 percent total error in capacity. This figure also includes errors caused by temperature and calibration, so that "drift" error must necessarily be considerably less than the maximum specified.

The greater the working stress and the higher the temperature, the more nearly viscous (irrecoverable) is the character of the "drift." For example, if the load of the steel spring mentioned above is doubled (within the elastic limit), the "drift" error would be 0.08 percent in one hour and 0.30 percent in 24 hours.

A rise in temperature increases the "drift" rate, but complications arise in determining the amount because

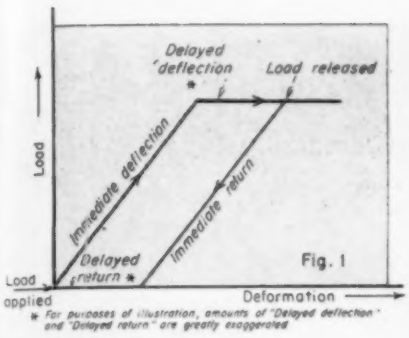


Fig. 1

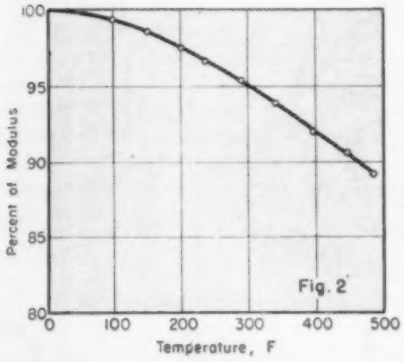


Fig. 2

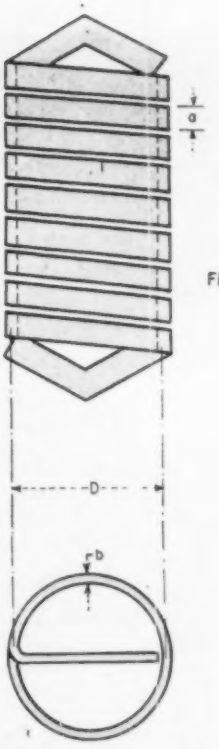


Fig. 3

For Rectangular Wire

$$\text{Rolling ratio} = \frac{a}{b} = \frac{\text{width}}{\text{thickness}}$$

$$\text{Spring index} = \frac{D}{b} = \frac{\text{mean dia}}{\text{thickness}}$$

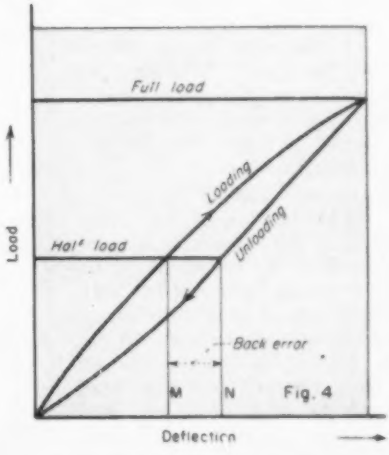


Fig. 4

Fig. 1—"Drift" is the delayed deflection that takes place in a spring at room temperatures after a load has brought about immediate (noticeable) deflection. Term "creep" applies to delayed deflection which occurs at elevated temperatures.

Fig. 2—Elastic modulus of spring steel decreases appreciably as temperature rises, resulting in change of strength and rate.

Fig. 3—Experience has shown that springs formed from rectangular wire function properly when the rolling ratio is *three* and the spring index is *twenty*. Adherence to these values prevents occurrence of straight line error.

Fig. 4—Hysteresis loop for complete loading cycle shows "back error" caused by "lag" in material as load drops.

the modulus of elasticity of the material also changes with temperature. Fig. 2 shows the effect of temperature on the modulus of elasticity of steel, and indicates the severity of change in strength for steel springs heated above 100 Fahrenheit.

Straight Line Error. Hooke's law states that a straight line relationship exists between load and deflection, but recent investigations have proven there exists a deviation known as "straight line error." Sayre and deForest proved by mathematical analysis that this error can be brought under control when the spring is properly proportioned and also by using rectangular-section material. Best results are obtained by using a spring index of *twenty* (ratio of mean diameter of spring to wire thickness) and a rolling ratio of *three* (width of material to thickness of material). Fig. 3 illustrates these ratios.

Hysteresis. One of the important properties of springs used in high accuracy devices is mechanical hysteresis or "back error." This term describes the lag in the deformation of an elastic material during removal of a previously applied load. The load-deflection curve or hysteresis loop illustrated in Fig. 4 represents a spring at four successive points in a load cycle—at half load, full load, back half load and zero load. Although the curve begins at zero and ends at precisely the same point, the halves of the loop coincide only at full load.

Most materials have a "back error," *M-N* in Fig. 4, amounting to 0.1 to 0.2 percent of total deflection. For the special spring materials, such as Iso Elastic, this figure is considerably less and is usually no more than 0.02 percent of total deflection.

Modulus of Elasticity. The thermal coefficient of the modulus of elasticity determines the change in the rate of a spring resulting from a change in temperature. Spring steel, for example, has a temperature coefficient of -190×10^{-6}/deg. F, whereas special spring alloys have a range between $+10 \times 10^{-6}$/ deg F and -15×10^{-6}/deg F. The sign preceding the thermal coefficient value designates the direction of change, i.e.; the minus sign indicates a decrease in the spring rate or a weakening of the spring with increasing temperature. A steel spring that deflects 1.0 in. at 80 F moves only 0.991 in. at 30 F or a difference of 0.009 in. for a change of 50 F. The same spring made of Iso Elastic material having a thermal cofficient of -10×10^{-6} would exhibit a difference in deflection of only 0.0005 in. for the same 50-F temperature variation. Table I lists several spring materials, their properties and uses.

Spring Materials. Each material listed in Table I has properties that dictate its use in certain applications. The end use generally determines which material is best suited both from a cost point of view as well as for satisfying loading requirements. On the other hand, other factors such

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as resistance to corrosion and electrical properties may, in some instances, be of greater importance than either cost or loading requirements.

Spring steel is ordinarily used for precision calibrated springs intended for applications in which the range of temperature is not great enough to affect the overall accuracy of the indicator reading. If corrosion resistance is important, steel springs can easily be cadmium-plated or zinc-plated. However, if electrical conductivity is also required, then beryllium copper or phosphor bronze should necessarily be chosen. Whenever the temperature range of a given application is such that inaccurate readings result, one of the temperature-compensated alloys should be used.

Construction. Another type of error is introduced whenever a spring is extended. The outside diameter of a coil spring necessarily decreases when the spring is extended, and, since the length of wire in the spring is constant, rotation of the end hooks occurs. By making a spring in two equal parts, one-half as a right-hand helix and the other as a left hand helix, rotation of each half is neutralized and the end hooks remain in line throughout loading.

Calibration. Every spring for precision weighing is calibrated to a rate within specified tolerances. The rate of a spring can be obtained by dividing a change of load by the corresponding change in deflection, the result being a constant that is designated in pounds per inch. The accuracy of calibration depends entirely upon the application and the cost increases considerably when a high degree of accuracy is required. Springs can readily be calibrated to within a few thousandths of an inch per inch of deflection if the application justifies the attendant cost.

The usual requirements for precision springs used in computing and similar scales call for an accuracy of 0.02 to 0.05 percent of the spring rate. Springs for aircraft use, such as spiral springs for fuel flowmeters, or extension springs for motor governors, require an accuracy of approximately 1.0 percent of the spring rate.

Calibrators. To meet and maintain exacting requirements for spring rate, a calibrator is used. Most calibrators consist of a sheet metal clamping arm that has been carefully designed. It is attached to the end coil of the spring in a position that gives the desired load-deflection characteristics. The location of the calibrator is determined by moving it about the end coil until the proper rate is obtained.

The sheet metal type of calibrator and its proper assembly on the end of coil of a spring are shown in Fig. 5. This type of calibrator is used extensively with rectangular extension springs in precision scales (Fig. 5) in which straight line characteristics as well as calibration are important. If recalibration of the springs is necessary, care must be taken in moving this type of calibrator, because inaccuracy will result if the clamping arm is not properly replaced. It is important that the coil and the shim be seated completely on the bottom of the clamping leg prior to retightening the self-tapping screw.

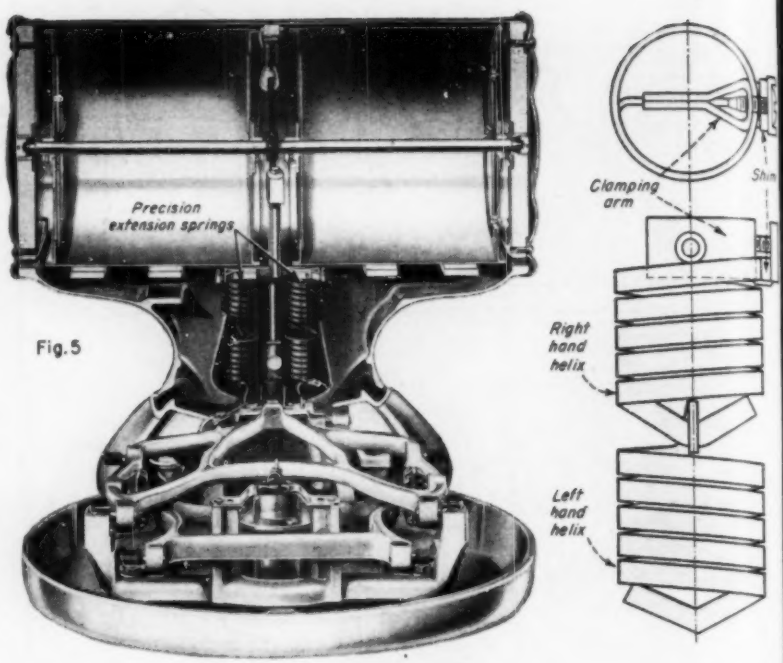


Fig. 5

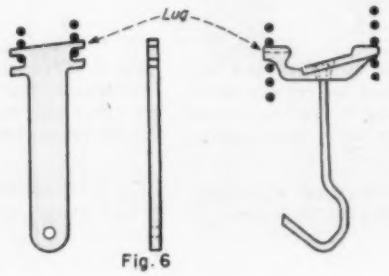


Fig. 6

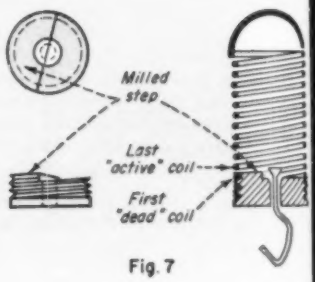


Fig. 7

For springs made of round wire, other types of calibrators are generally used. The two sheet metal designs shown in Fig. 6 are limited in their usage because the height of the lug must be greater than the maximum deflection per coil. When this is not the case, the number of active turns will change as the spring is extended to full capacity. If the last active coil leaves the calibrator during the load cycle, the condition known as "leaving the calibrator" occurs and the performance of the spring is influenced to the point of changing the spring rate.

The plug type calibrator illustrated in Fig. 7 is designed to overcome the problem of "leaving". This calibrator has a standard V-type thread machined on the OD and the "spring" end is milled to provide a definite "leaving point" for the last "active" coil. This type of calibrator is used extensively in the aeronautical field where the best possible straight line relationship must be obtained with round wire springs. Additional requirements are minimum hysteresis and "drift" errors, and a minimum change of spring rate resulting from temperature variation.

The plug type calibrator should be

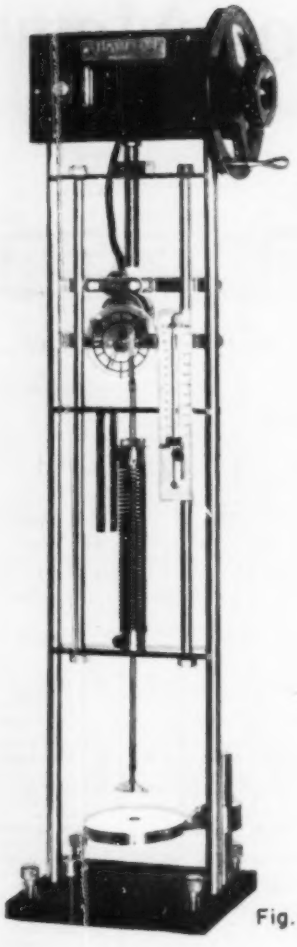


Fig. 8

Table I – Properties and Uses for Various Spring Materials

Material and Nominal Composition, %	Temp. Coef. of Modulus of Elast.	Special Properties Typical Applications
Iso Elastic Nickel 36.0 Chromium 8.0 Molybdenum 0.5	-10×10^{-6}/deg F to $+15\times^{-6}$/deg F	Low temperature coefficient of *E*; good corrosion resistance, hysteresis and drift properties. Temp. compensated springs for weighing devices, computing scales and aircraft instruments.
Ni Span C Nickel 42.0 Chromium 5.0 Titanium 2.5 Carbon 0.06	-10×10^{-6}/deg F to $+10\times10^{-6}$/deg F	Low temperature coefficient of *E*. Instrument springs where temperature change is important.
Beryllium Copper Beryllium 2.0 Copper 98.0	-35×10^{-5}/deg F	Good corrosion resistance and electrical properties. Electrical instrument springs, hairsprings and motor brush springs.
Phosphor Bronze Copper 92.0 Tin 8.0	-36×10^{-5}/deg F	Good corrosion resistance and electrical properties. Electrical switches, motor brush springs and hairsprings.
Spring Steel Carbon 0.6–0.95 Manganese 0.3–1.10	-190×10^{-6}/deg F	High elastic limit. General use.

Fig. 5—Precision computing scale has two temperature-compensated extension springs that are calibrated to accuracy of 0.1 percent of the spring rate. Details of sheet metal clamp show proper positioning of arm and shim on rectangular wire.

Fig. 6—Sheet metal calibrators for round-wire springs are not as accurate as clamp type because height of lug exceeds maximum deflection per coil.

Fig. 7—Plug type calibrator permits precise calibration of round-wire springs by keeping last "active" coil and first "dead" coil in relatively normal positions. Milled "step" provides a definite "leaving point" for last "active" coil.

Fig. 8—Precision round-wire spring in Abraham consistometer has a plug-type calibrator at each end. Accuracy is about 0.4 percent of spring rate.

so designed as to increase the diameter of the "dead" coils of the spring approximately 0.005 to 0.010 in. when assembled. The ends of this type calibrator should be milled parallel to the pitch of the thread of one complete coil, in order to prevent a change in the number of active coils during loading.[1] Thus the spring rate remains constant throughout the full deflection of the spring. This type of calibrator is used in the Abraham consistometer, Fig. 8, wherein the best straight line characteristics are required for a round wire assembly.

Space Considerations. In the design of instruments and mechanisms, particularly small and complicated ones, the spring should be considered a principal element of the design. Too often the spring design is left as a final detail, to be determined on a trial and error basis. In such instances, it is common to find that the experimental spring is either overstressed or has a short cyclic life; or the experimental model, which may be satisfactory, is made of steel and the final specifications require it to be made of a temperature-compensated alloy. The steel specifications are therefore turned over to the spring manufacturer who designs an equivalent spring using the special alloy. This practice often results in a spring having outside dimensions that exceed those used as a basis for positioning adjacent parts. Extensive and costly redesigns sometimes result in an effort to provide additional space.

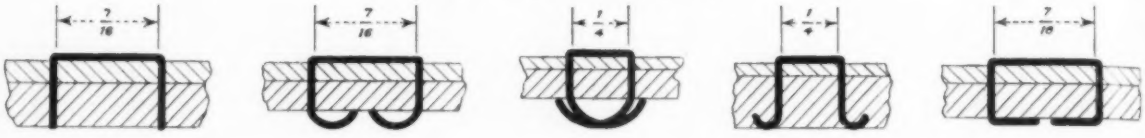
Ample clearance should also be allowed adjacent to a spring that is to operate inside a tube or outside a rod. If it is not borne in mind that the diameter of a spring changes with load, and that there are manufacturing tolerances on the spring diameter and the tube or rod, clamping or binding of the spring can result.

Another element of design sometimes overlooked is that of incorporating a means for adjusting the hook length of the spring. When this provision is made, the spring rate is the critical factor. If the designer requires an accurately-held hook length in addition to a specific spring rate, the cost of the spring rises rapidly, but generally it is not difficult to accommodate the instrument to a spring manufactured to meet normal tolerances.

A final point worthy of note is that the designer should take into account the worst possible loading of a spring, and allow for the absolute maximum deflection to which it will be subjected. A specification that applies only to the deflection of a spring when in operating position and not to a larger deflection that occurs when the spring is installed, can be the cause of unsatisfactory performance.

Design Data for Metal

TYPES OF STITCHES



Unclinched | Standard loop | By-pass loop | Outside loop | Flat clinch

MAXIMUM STITCH PENETRATION

Loop-clinch stitch

Metals	Metal to Metal thicknesses (in.)		Metal to Non-metal thicknesses (in.)		Non-metals
Aluminum (soft) 3SO, 52SO, 61SO, Alclad 24SO, R301-O, R301-W, 75SO, 75SW	0.093	0.093	0.125	1/2	Sheet cork
Aluminum (1/2 hard) 3S-H14, 52S-H34	0.064	0.064	0.080	3/8	Leather
Aluminum (hard) 61ST6, Alclad 24ST3, Alclad 24ST36, R301-T, 75ST6	0.040	0.040	0.064	1/4	Sheet asbestos
Aluminum extrusion	0.062	0.062	0.093	1/2	Fiberboard
1010 Cold-rolled steel	0.0475	0.0475[1]	0.080	1/2	Sponge rubber
Hot-rolled steel	0.0475	0.0348[1]	0.0625	1/4	Solid rubber
Galvanized sheet	0.0348	0.0348[1]	0.0475	3/8	Phenol[2]
Stainless, Type 302, full hard	0.010	0.010	0.020	1/16	Plastics[2]
Stainless, 1/2 hard	0.012	0.012	0.025	3/8	Standard Masonite
Stainless, 1/4 hard	0.015	0.015	0.030	1/4	Tempered Masonite
Stainless, annealed	0.020	0.020	0.040	3/8[3]	Solid wood
Sheet brass, soft	0.030	0.030	0.050	3/8[3]	Plywood
Sheet copper	0.035	0.035	0.064		

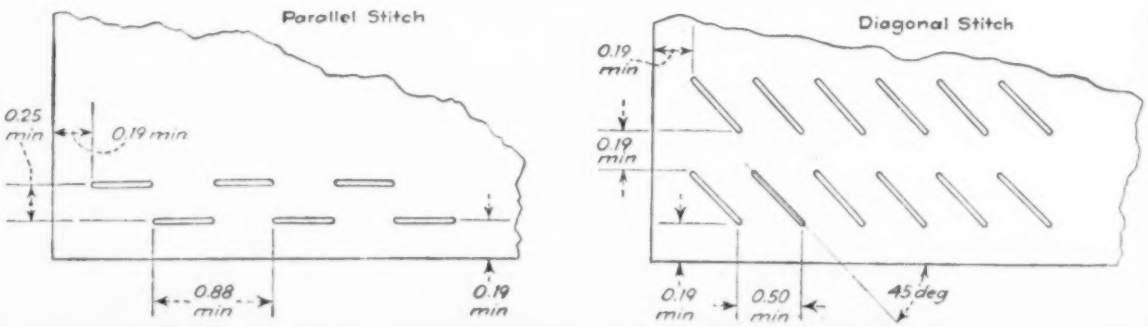
Flat-clinch stitch

Metals	Metal to Metal thicknesses (in.)		Metal to Non-metal thicknesses (in.)		Non-metals
Aluminum (soft) 3SO, 52SO, 61SO, Alclad 24SO, R301-O, R301-W, 75SO, 75SW	0.093	0.093	0.125	1/8	Sheet cork
Aluminum (1/2 hard) 3S-H14, 52S-H34	0.064	0.064	0.080	1/16	Leather
Aluminum (hard) 61ST6, Alclad 24ST3, Alclad 24ST36, R301-T, 75ST6	0.040	0.040	0.064	1/16	Sheet asbestos
Aluminum extrusion	0.062	0.062	0.093	1/16	Fiberboard
1010 Cold-rolled steel	0.0348	0.0348	0.0348	3/16	Sponge rubber
Hot-rolled steel	0.0348	0.0348	0.0348	1/4	Solid rubber
Galvanized sheet	0.0312	0.0312	0.0312	1/16	Phenolics[2]
Stainless, Type 302, full hard	0.010	[4]	0.010	1/16	Plastics[2]
Stainless, 1/2 hard	0.012	[4]	0.012	1/16	Standard Masonite
Stainless, 1/4 hard	0.015	0.015	0.015	1/16	Tempered Masonite
Stainless, annealed	0.020	0.020	0.020	1/16	Solid wood
Sheet brass, soft	0.030	0.030	0.040	1/16	Plywood
Sheet copper	0.035	0.035	0.045		

[1] 50RB or softer.
[2] Must be soft enough to allow penetration without cracking.
[3] Grain structure may cause leg wander in thicknesses over 3/16 in.
[4] Stitching full-hard or half-hard stainless to itself not recommended.

Example: A sheet of 0.093 in. 24S0 Alclad can be stitched to a 0.020 in. sheet of annealed steel with either type of stitch. This same Alclad sheet can be stitched to 1/4 in. thick tempered Masonite.

RECOMMENDED MINIMUM SPACING (based on maximum holding capacity)



Wire Stitching

Acme Steel Co.

STITCH STRENGTH

Ultimate Shear Strength using Type 290 wire, flat clinched through 24 ST aluminum.

Thickness of Sheet, in.		0.032	0.040	0.051
Type of Loading		Shear Strength, lb. per stitch		
Perpendicular		431	557	601
Parallel		433	476	480
Diagonal		Same as perpendicular but preferable because of both parallel and perpendicular coverage		
Tension*		196	232	252
Butt		Not Recommended		

* Recommended with reinforcing material only

WIRE SIZES AND PROPERTIES

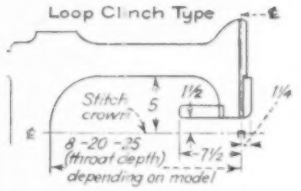
STANDARD SIZES

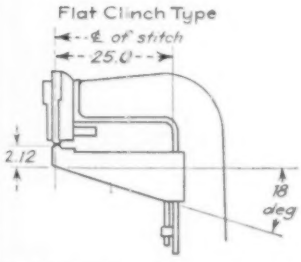
Gage	Dia. (in.)	Use
18	0.0475	98% or more of all applications
20	0.0348	1.5% of all applications
16	0.0625	0.5% or less of all applications

PROPERTIES

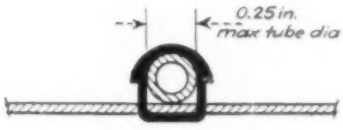
Tensile Strength of Hi-Carbon types (psi)	230.....220,000 to 249,000 260.....250,000 to 289,000 290.....290,000 to 319,000 330.....320,000 to 360,000
Ductility	All sizes and grades withstand 180 deg. bend without fracturing or breaking
Finishes	Tinned, Galvanized, Liquor, Bright in all commercial standards
Size Tolerance	Plus or minus 0.001 in. to diameter specified and not more than 0.001 in. out of round

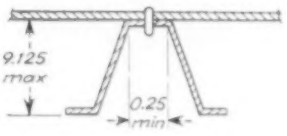
BASIC MACHINE DIMENSIONS — TYPICAL STITCHED SECTIONS

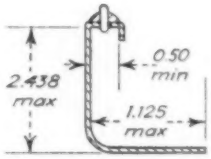


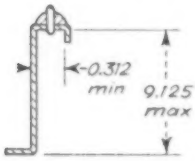


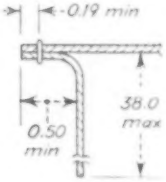
Basic stitching machine dimensions are shown above. Maximum jaw opening is 0.75 in. Limiting dimensions of typical sections are given at the right

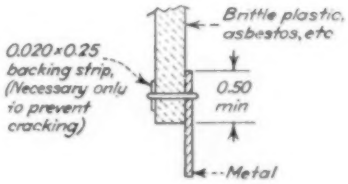


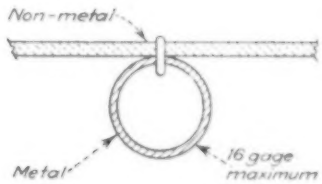


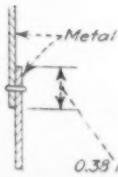


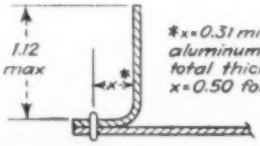


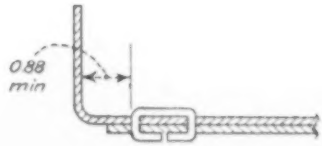












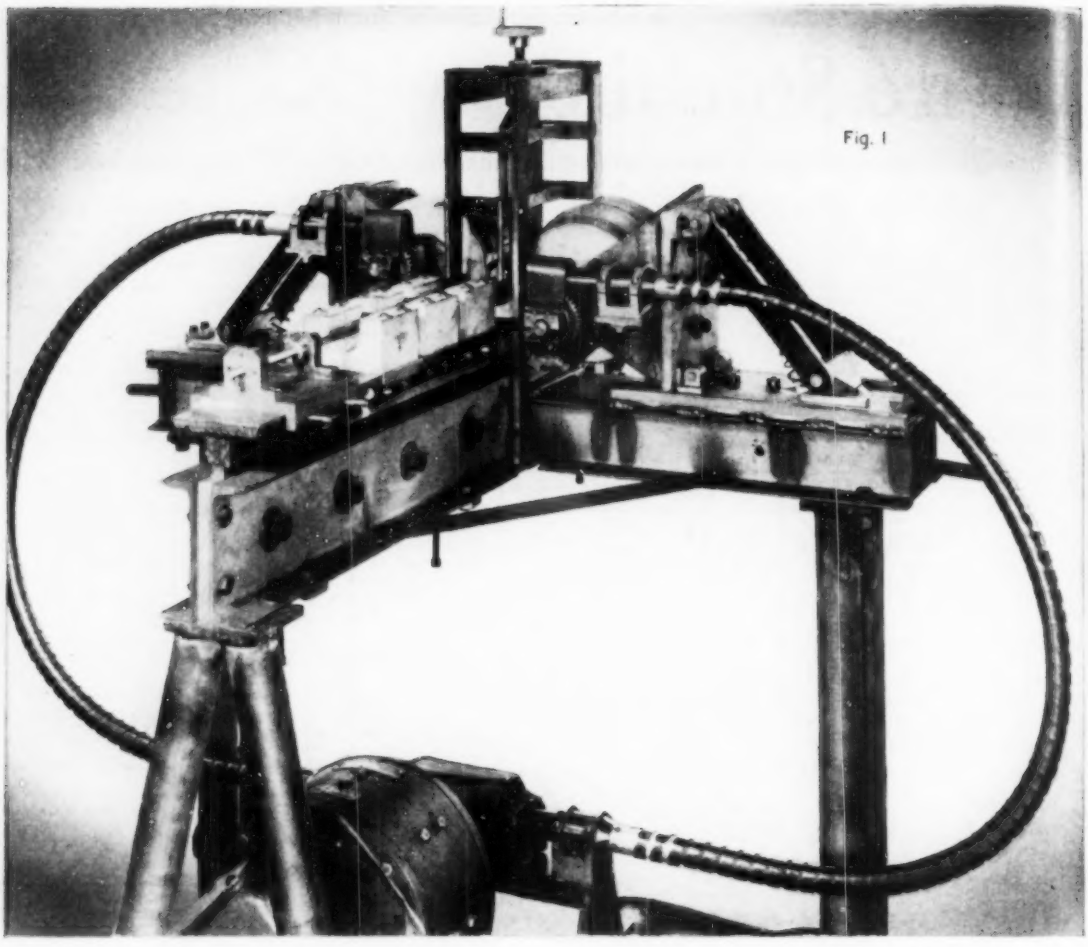


Fig. 1

Wax Filamented Model Billets Aid Study of Material Flow

EXPERIMENTS, conducted with a quarter-scale model piercing mill and wax billets containing colored wax filaments, have revealed much information concerning the flow or deformation of material that occurs in forming a billet into a hollow cylinder on a Mannesmann type piercing mill.

Observation and measurement of the displacement and change of shape of the colored wax filaments show how material flowed in various stages of the piercing process and in different portions of the original billet.

For good visibility of its working parts during operation, the model mill as shown in Figs. 1 and 2, was of open construction.

The mill is designed to be highly flexible in adjustment and settings. The rolls are driven by a worm and worm gear through flexible shafting from a variable speed d-c motor. Any desired roll speed from 22 to 88 rpm is obtainable. The roll obliquity angle can be varied from 0 to 15 deg. Adjustment of draft and shoes is accomplished by means of screws.

Since the wax billet is pierced at a temperature of 110 to 115 F, hard maple wood is used for the rolls, shoes, outlet guides, and piercer points.

Although the model mill is patterned after production equipment in all essential respects, the rolls are somewhat longer in proportion to their diameter than are those in the production mill. This departure allows more latitude in experimenting with small roll angles than is available on the production mill.

A quick release mechanism permits stopping the piercing action at any desired point. As shown in Fig. 2,

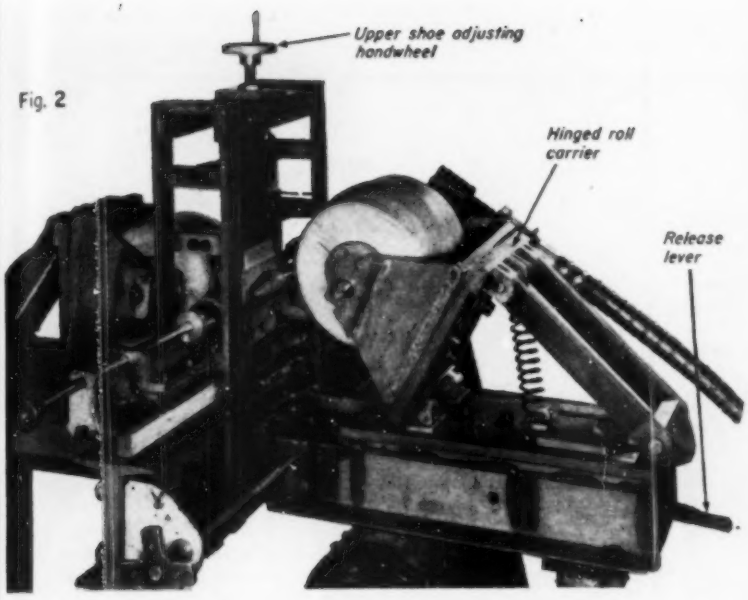


Fig. 2

Fig. 2—Open construction of the model mill aids visibility of the working parts during operation. To obtain latitude in experimenting with small roll angles, the rolls in the model mill are longer in proportion to their diameter than are those in the production mill.

Fig. 3—Equipment for molding color filamented wax billets. (A) Cylindrical mold. (B) End plates and core wires. (C) Cored billet in place for injection of filaments. (D) Stool containing molten colored wax. Cored holes are filled by pumping the billet up and down like a piston. (E) Sleeve to contain overflow of colored wax.

Fig. 2—Model piercing mill constructed for forming wax filamented billets into hollow cylinders simulates rolling and piercing of the Mannesmann process.

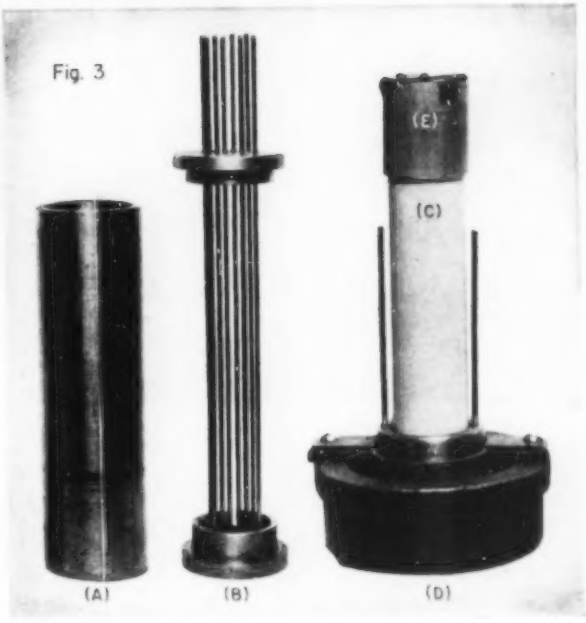


Fig. 3

J. L. HOLMQUIST
Director of Research, Spang-Chalfant Division,
The National Supply Company

Displacement and change of shape of colored wax filaments in a wax billet show how material flows in the stages of the Mannesmann process. Analysis of observations in terms of the type and amount of deformation the material is subjected to in the rolling and piercing operation.

the roll carriers are hinged so that the rolls can be swung outward away from the billet by springs when a latch mechanism is tripped.

The model billets are made by casting molten wax into a mold, Fig. 3, containing ten core wires. The wires are spaced radially in the mold on two diameters perpendicular to each other; six wires on one diameter and four on the other. The spacing of the four wires on one diameter is such that radially they fall between the six wires on the other diameter. After solidification the wax billet is stripped from the mold, the core wires are withdrawn from the billet, and the holes formed by the wires are filled with molten wax of the same composition except that a wax-soluble dye is added. The holes are filled by pushing one end of the cored billet into a container of molten colored wax, then pumping the billet up and down like a piston.

The properties of the wax are such that it is firm at room temperature, is plastic over a wide enough temperature range so that temperature control for piercing is not too critical, and is not too "slippery" to prevent the rolls siezing and feeding the billet through the mill.

Although the method followed produces filamented billets that are satisfactory for most of the program requirements, measurements show that at times the filaments vary in diameter along their length, a maximum variation of about 0.030 in. has been noted. Work is being done to improve the uniformity of the filament diameter.

After piercing the wax billet on the model mill, the wax is scraped away to reveal the filaments, Fig. 4. From observations of the changes in shape

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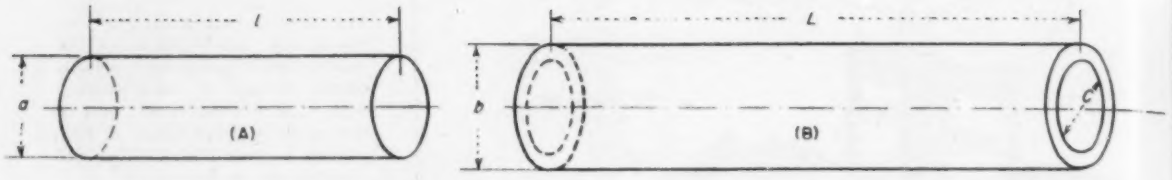
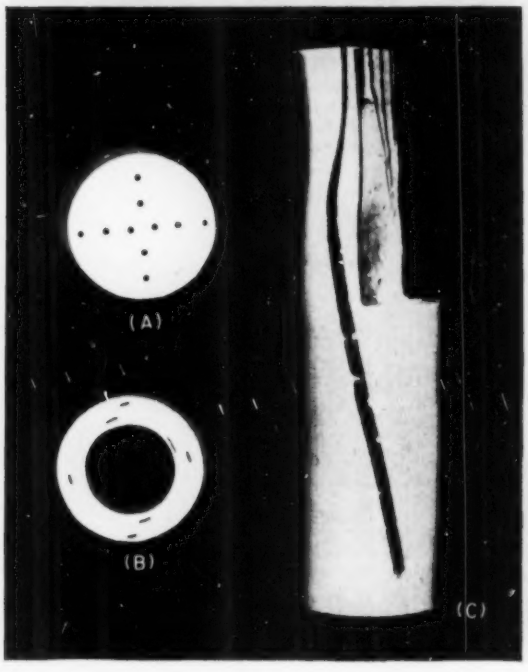


Fig. 4—Sections of filamented wax billets. (A) Section showing pattern of filaments. (B) Pierced billet showing deformation of filaments. (C) Partially pierced billet showing degree of twist in outermost filament.



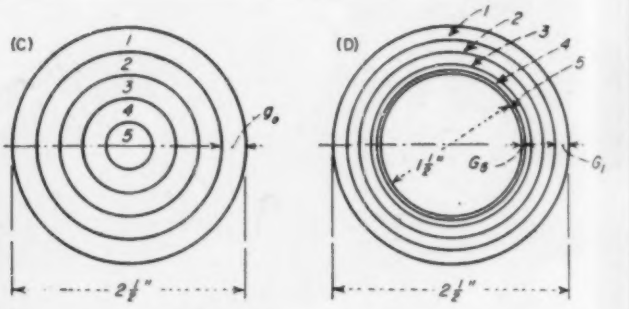


Fig. 5—(A) Original billet. (B) Shell made by piercing original billet. (C) Tubular elements in original billet. (D) Position of corresponding tubular elements in pierced shell.

Table I—Outside and Inside Diameters of Elements in Billet and Shell

Element No.	In Billet			In Pierced Shell		
	O. D., in.	I. D., in.	Annular Area A_B, sq in.	Annular Area A_s = 0.66 A_B, sq in.	O. D., in.	I. D., in.
1	2.5	2.0	1.767	1.164	2.5	2.212
2	2.0	1.5	1.375	0.906	2.212	1.933
3	1.5	1.0	0.982	0.648	1.933	1.710
4	1.0	0.5	0.589	0.389	1.710	1.556
5	0.5	0	0.196	0.129	1.556	1.5

and position of the filaments as compared with their shape and position in the original billet, deductions are made as to the type and amount of deformation the material is subjected to in the rolling and piercing operation.

In the piercing of a billet certain deformations occur that are essential to the change in shape from a solid round to a hollow cylinder. In addition, other deformations occur that are unessential to the shaping operation. In this discussion, the essential deformations will be referred to as "basic" deformations and the unessential ones will be called "redundant" deformations.

Basic Deformations

An original billet having the length l is shown in Fig. 5(A) and the pierced shell made therefrom having the length L is shown in Fig. 5(B). Since the volume of the material is the same in both and the length of the shell is greater than the billet, the cross-sectional area of the shell is smaller than that of the billet.

To present briefly the method of transposing the pattern of the filaments used in the billet into their corresponding pattern in the pierced shell, imagine the billet to be made up of four telescoped tubular elements and a central solid core element as shown in Fig. 5(C). When this billet is pierced into the shell shown in Fig. 5(D), the original elements are transformed into the tubular elements as respectively indicated.

The cross-section area of the 2½ in. dia billet is 4.909 sq in., and that of the 2½ in. O.D. by 1½ in I.D. shell is 3.242 sq in. The length L of the shell, therefore, will be

$$L = 4.909l/3.242 = 1.515l$$

the billet, therefore, elongates 51.5 percent during piercing. Since all the billet elements are stretched out to the same length of shell, they all elongate 51.5 percent. Since the volume of each element remains constant, the annular area of each element after piercing is 1/1.515 or 0.66 times its area before piercing. From these relationships, data like those shown in Table I are calculated.

As can be noted from Fig. 5(D), the thickness G_1 of element No. 1 is less than thickness of g_1 of the corresponding element in the billet. Since the outside diameter of element No. 1 is the same in shell and billet, the reduction in thickness results only from the lengthwise elongation of the material. The thickness of the elements is reduced more and more as the inner surface is approached.

For the inner elements, the diameter of the elements in the shell is greater

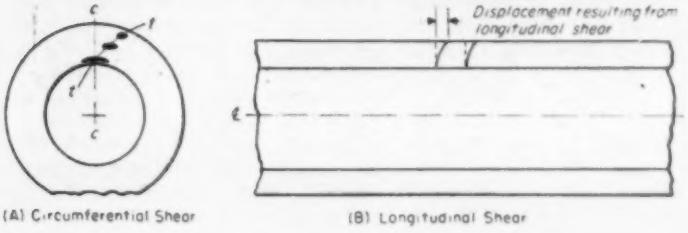


Fig. 6—(A) Circumferential shear displaces filaments that were originally on a radius in the billet to positions on a spiral curve in the shell. (B) Longitudinal shear.

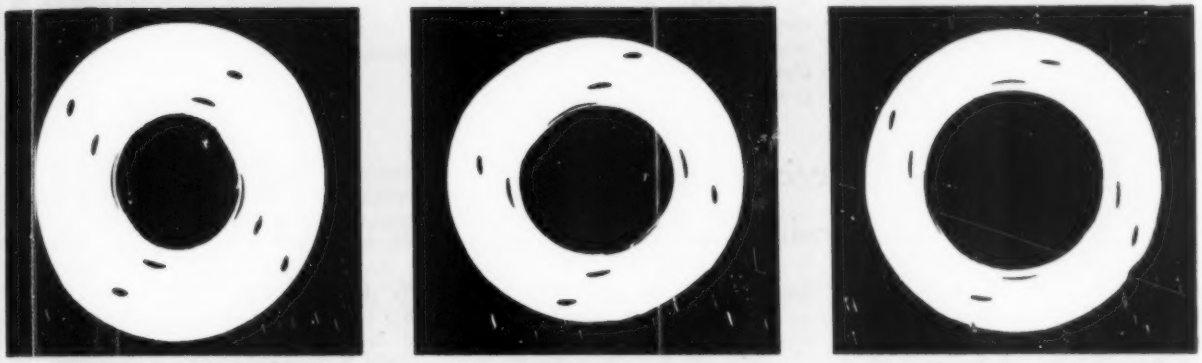


Fig. 7—Photographs of transverse sections through filamented billet at four stations along the length of the piercer point, which show experimental evidence of the circumferential shear.

Fig. 8—Section of wax shell showing longitudinal displacement of the helical filaments. The direction of billet travel in piercing is from left to right.

than that of the corresponding elements in the billet, consequently, the material in these elements is stretched or elongated circumferentially. The reduction in thickness of these elements results from both longitudinal and circumferential elongation.

The foregoing remarks apply only to the overall change from billet to shell. What is happening just where the point is making the hole in the billet cannot be so simply predicted. Transiently, where the point is opening the hole, for example, the longitudinal extension may not be uniform across the section. This experimental method will enable a check on such questions. If the longitudinal extension is not the same across the section, then some filaments will have different areas than the others.

When a given billet is converted into a given shell, the basic deformations are inherent to the change in size and shape. Since these deformations are governed by the geometry, the material obviously makes no difference in the results obtained in piercing. The wax billets, therefore, show the same degree and distribution of the basic deformations that occur in a steel billet when it is pierced.

Redundant Deformations

Three redundant deformations are observed to occur in the piercing of wax billets. These are: Twist; circumferential shear; and longitudinal shear. Twist is evidenced by the spiral filament seen in Fig. 4. Circumferential and longitudinal shear are shown diagrammatically in Fig. 6. Experimental evidence of the occurrence of circumferential shear is shown in Fig. 7, and in Fig. 8 the occurrence of longitudinal shear.

One way of visualizing the circumferential shear is to imagine the shell to be made up of thin close fitting tubes telescoped together. Progressing inwardly, as each tube is rotated a small amount it carries the outer ones with it, so that the total angle through which the outer surface is displaced with respect to the inner surface is the sum of all the angular displacements given to each of the tubes. This type of deformation is revealed by the filaments as shown in Fig. 6(A). The filaments that were originally disposed along the radius *cc* in the billet are displaced to positions along the curve *tt* as a result of circumferential shear.

Longitudinal shear, Fig. 6 (B), similarly can be visualized with the model of a shell made up of telescoped thin wall tubes. In this analogy, the outer tubes are slipped forward relative to the inner tubes, forward meaning the direction in which the billet is going through the mill.

A question that naturally arises is

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whether the flow or deformation of the wax billet during piercing on the model mill fairly represents the flow that occurs in steel when pierced on production equipment. Certainly there can be no difference with respect to the basic deformations, they must be identical. It can hardly be doubted that the same type of redundant deformations occur in the two cases, although there might be a difference in degree.

With regard to the twist deformation, for example, the frictional characteristics of wax on wood may be different than those of hot steel on cold steel rolls. The strength of the wax billet to resist twisting may be different, relative to the frictional forces tending to twist it, than that of hot steel. Many wax shells, however, have been pierced in which the angles of twist compare with those observed in piercing steel.

With respect to circumferential and longitudinal shear, no experimental evidence is at hand to indicate how closely the deformations in wax compare with those in steel.

On heavy wall wax shells, the redundant deformations are observed to be smaller than on thin wall shells. The basic deformations, of course, are also smaller. These observations are consistent with the idea that as the size of the hole is decreased, less work is done on the material.

The redundant deformations do not contribute usefully to the forming of the shell from the billet. No doubt they consume power and make additional demands on the ductility of the material. One object of the project is to discover ways of reducing them.

Deduction of Material Deformations From Shape and Position of Filaments

Consider first the effect of the basic deformations on the position of the filaments in the transverse section of the pierced billet. Referring to Fig. 9 (A), which shows the transverse section of a billet containing a tubular element, and to Fig. 9 (B), which shows the transverse section of a shell pierced from the billet Fig. 9 (A) and the displacement of the corresponding tubular element, where

r = internal radius of tubular element in the billet, in.

R = internal radius of corresponding tubular element in shell, in.

l = length of the billet, in.

L = length of corresponding shell, in

a = outside radius of billet, in.

B = outside radius of shell, in

C = inside radius of shell, in.

v_b = volume of material in a solid cylinder of outside radius r and length l, cu in.

v_s = volume of material in a hollow cylinder of outside radius R and length L, cu in.

V = volume of material in the billet, cu in.

then

$$V = \pi a^2 l = \pi (B^2 - C^2) L$$

or

$$L/l = a^2/(B^2 - C^2) \qquad (1)$$

also

$$v_b = v_s = \pi r^2 l = \pi (R^2 - C^2) L \qquad (2)$$

substituting Eq (1) in Eq (2)

$$r^2/(R^2 - C^2) = a^2/(B^2 - C^2)$$

rearranging the terms and solving

$$R = \sqrt{\frac{r^2 (B^2 - C^2)}{a^2} + C^2} \qquad (3)$$

hence Eq (3) gives the value of the radius R in the pierced shell corresponding to a given radius r in the original solid billet.

An important relation that affects the shape of the filament is shown in Fig. 9(A). Consider the circle of radius O that is expanded to a larger radius Z. During piercing of the billet, the arc NN on the smaller circle is stretched to the arc $N'N'$ on the larger circle. These arcs subtend the same central angle, or the same fraction of

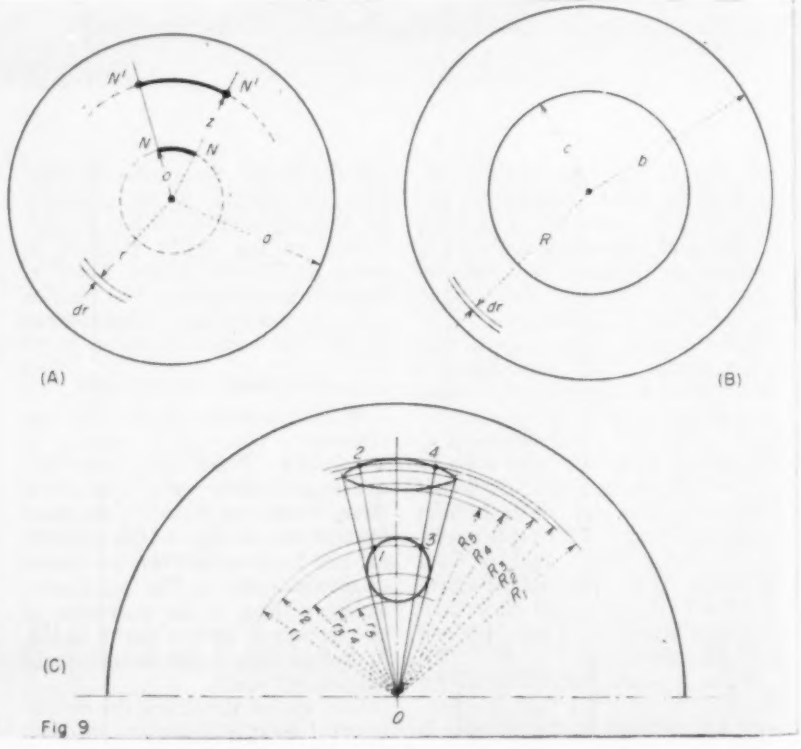


Fig 9

Fig. 9—Effects of the basic deformations on the position and shape of filaments and arcs of tubular elements in the transverse section of the pierced billet. (A) Transverse section of billet. (B) Transverse section of shell. (C) Original circular filament becomes oval.

Fig. 10—Methods of measuring shear and of determining change in shape of filaments resulting from circumferential shear in processing operations.

Fig. 11—(A) Longitudinal section of shell wall showing displacement resulting from shear. (B) Method of separating the circumferential and longitudinal shear effects on the circumferential displacement of the filaments. In the shell, the filaments assume the shape of helical springs.

the circumference of their respective circles.

In Fig. 9 (C) is shown the use of this relation in determining the change in shape of the filament as its position is displaced radially in accordance with Eq (3). The original circular filament becomes oval in shape because of the circumferential stretching and radial thinning. The photographs reproduced in Fig. 7 show transverse sections through a partially pierced filamented billet at various stations along the length of the piercer point. The twist imparted to the shell is clearly revealed by the filaments.

Where

P = pitch of the filament helix, in.
D = diameter of the filament helix, in.
S = length of one turn of the helix, in
g = helix angle

$$S = \sqrt{\pi^2 D^2 + P^2}$$

$$g = \tan^{-1}(\pi D / P)$$

The changes in position and shape of the filament in transverse sections of the shell that result from basic deformations are not altered by the twisting imparted to the shell.

The evidence revealed by the filaments of existing circumferential shear is shown diagrammatically in Fig. 10. Circumferential shear transposes the original circular section of the filament to an oval shape.

The magnitude of the shear is measured by the angle q in Fig. 10 (A). The transposing operations can be explained by reference to the points a and e on the periphery of the original filament. Arc SS is drawn from the axis of the shell or billet as a center to pass through points a and e. The amount of displacement by shear of particles along the arc SS is the distance cd. Hence point a is moved the distance cd along the arc SS to the displaced position at point b. In the same manner, point e becomes point f. The displaced positions of other points on the periphery of the original filament are found by a similar procedure.

A filament that has an oval shape as a result of basic deformations is shown in Fig. 10 (B). The same transposing procedure used with the circular filament in Fig. 10 (A) can be used to determine the change in shape of this filament resulting from circumferential shear.

One more effect of circumferential shear can be noted in Fig. 10 (A). A radius OP, drawn through the center of the sheared filament, and the major axis of the filament define the angle U by which the filament is tilted by the circumferential shear action.

Both the ovalizing and tilting effects of circumferential shear are shown in Fig. 7. In the sections where the hole made by the piercer point is small, the outer filaments have been little affected by the basic deformations. They would still be circular except for circumferential shear. In sections where the hole is larger, the ovalizing effect resulting from the basic deformations is greater and obscures that which is caused by circumferential shear. The tilting action, however, is still evident in many of the filaments.

Longitudinal shear can be measured on longitudinal sections through the shell like that shown in Fig. 8. Such a section is represented diagrammatically in Fig. 11 (A). The curve tt represents the displacement resulting from shear. The shear strain at any point in the wall thickness is obtained from the slope of the displacement curve at that point.

Separation of Shear Effects

The separation of the circumferential and longitudinal shear effects on the circumferential displacement of the filaments in transverse sections of the shell is shown in Fig. 11 (B). The solid filaments along curve tt are displaced as a result of both effects. The dash line ovals along curve $t't'$ represent the position the filaments would have in the shell if the displacement was caused by circumferential shear only.

In the shell, the filaments have assumed the shape of helical springs. In the shell wall, the filaments are in the relation of a number of helical springs nested one inside the other.

Fig. 10

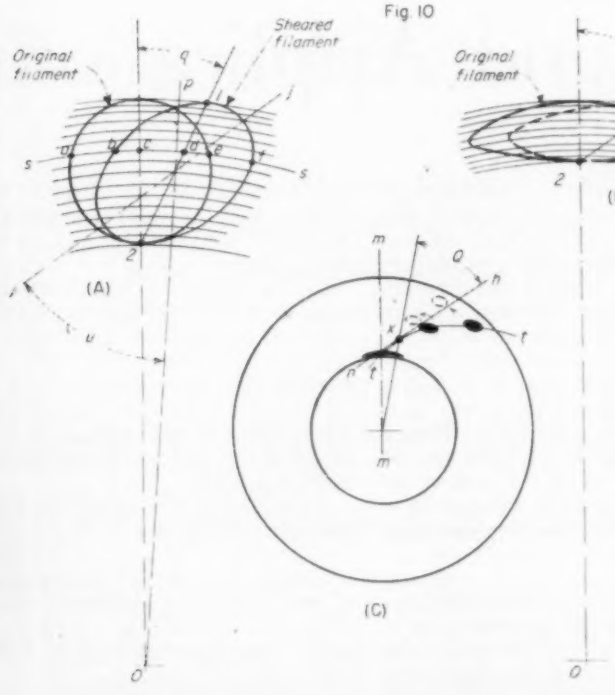
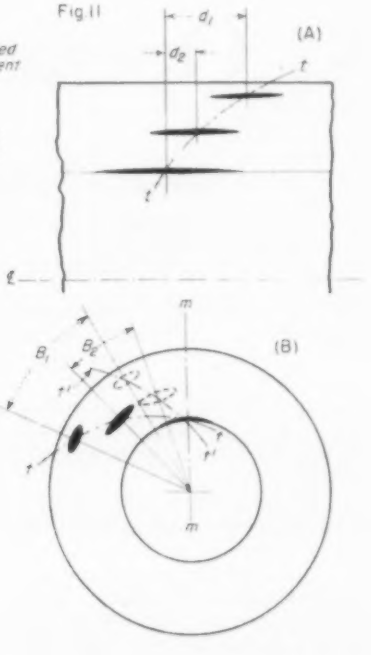


Fig. 11



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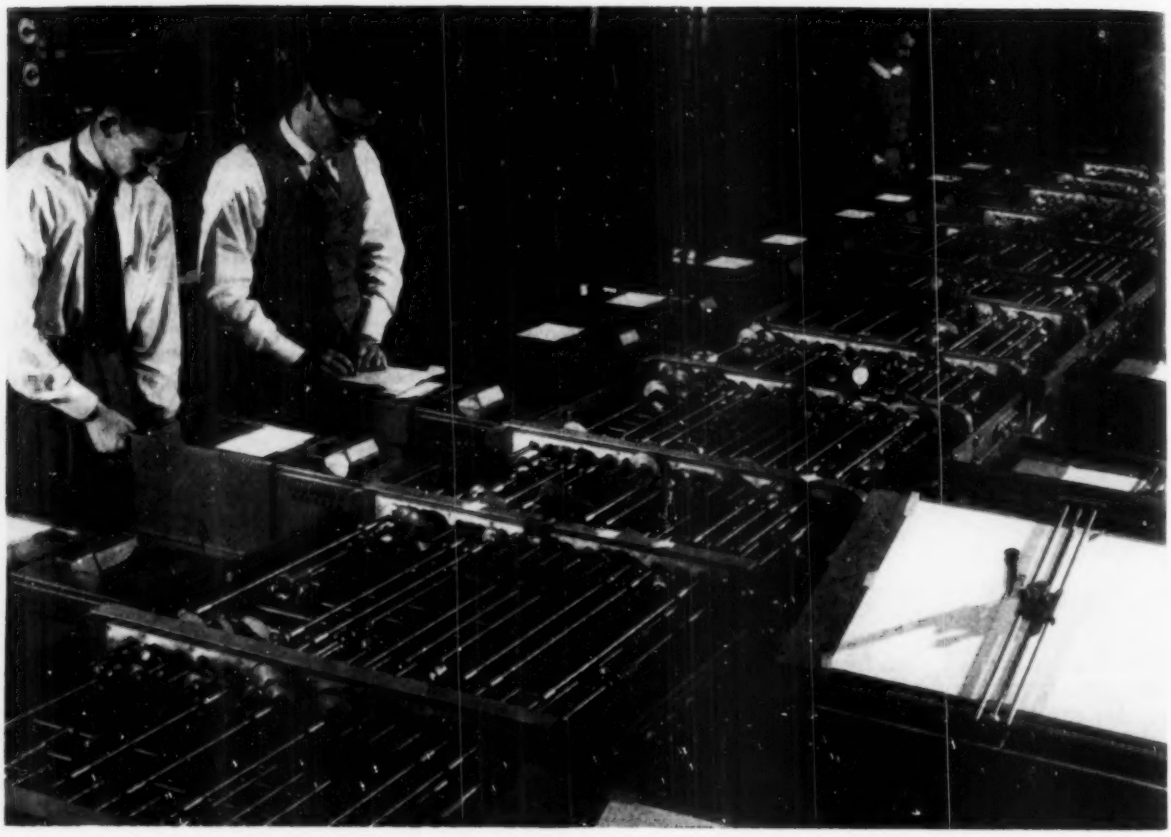

Fig. 1—Overall view of a differential analyzer. Several sets of differential equations can be solved simultaneously on the machine. Or, if the problem is extremely complex, the entire machine may be assigned to the working of it. Input tables are at the right of the picture. These tables make it possible to feed graphical problems directly into the differential analyzer for solution.

Operation and Applications

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LIKE OTHER AUTOMATIC COMPUTERS, the differential analyzer, such as that pictured in Fig. 1, is becoming an essential instrument in American research and design. This computing machine provides—quickly and automatically—solutions to systems of differential equations. In addition to its speed of computation, the analyzer can include in the solution the effect of non-linear relationships and empirical functions as they actually appear.

For example, in a guided missile problem, the drag effect of the air upon the missile depends upon the speed and altitude of the missile. The problem cannot be solved by classical methods because it is impossible to get a manageable equation relating drag to speed and altitude. On the differential analyzer the actual empirical relationship can be used, and the problem solved easily. Of course, use of the analyzer does not relieve the engineer of the responsibility of properly defining the system to be studied by a set of differential equations.

The machine is accurate. When a mistake occurs it is usually because the equations set up on the analyzer are not what the engineer means them to be. The user must find the basic equations that properly describe the system; must evaluate all the constants and functions; and must make sure that he has enough equations to completely describe it. If there are five variables in the problem (not counting time), there must be five independent equations—six would be redundant and four would be insufficient for one of the variables could not be found properly.

The differential analyzer is classed as an analog type computer. It does not solve the equations by manipulating digits but converts the elements of the equations into analogous mechanical movements. Thus, a quantity whose value is two might be represented in the analyzer as two revolutions of a shaft.

To expand on this explanation, consider the problems for which the differential analyzer is used. Ordinarily, the system to be studied consists of a set of simultaneous differential equations. For simplicity, assume that each of the equations are of the form

$$\frac{dV}{dt} = 0.2258\,I + 0.1428E \qquad (1)$$

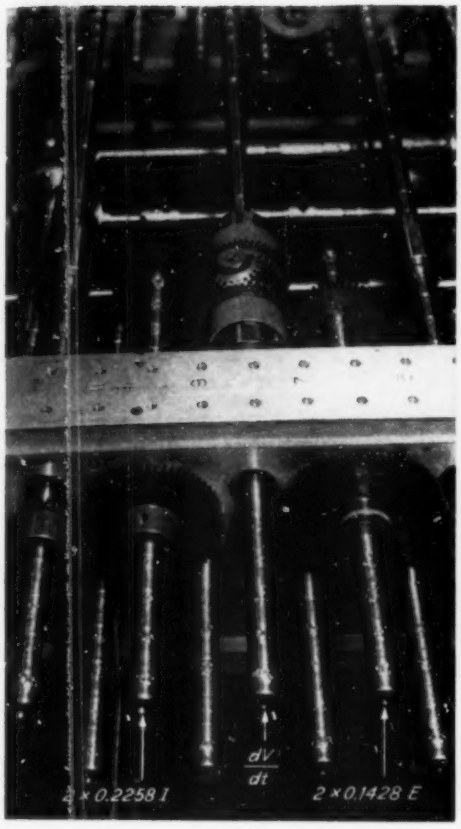

Fig. 2—Addition and subtraction section of the analyzer. Each shaft feeding into a differential mechanism corresponds to a variable in an equation.

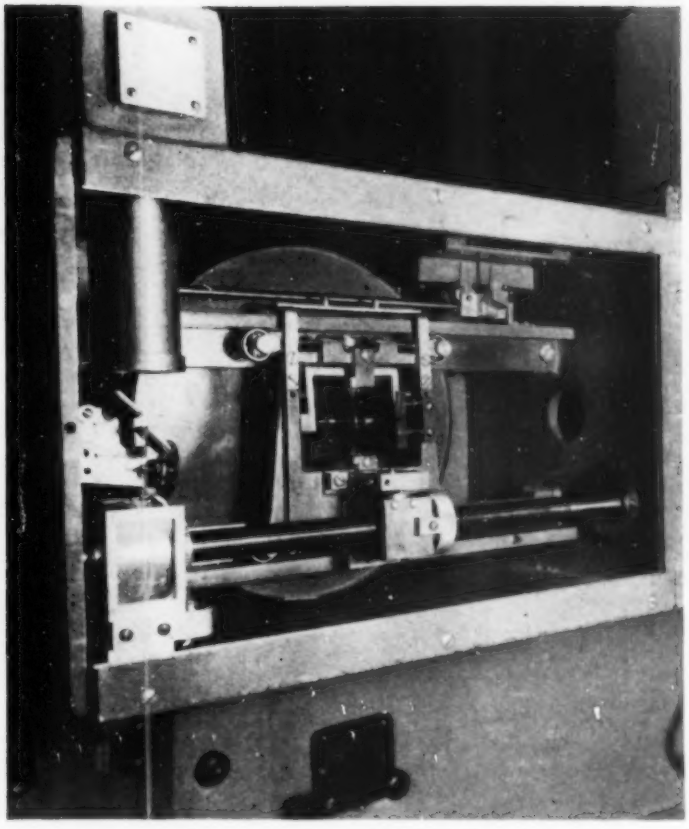

Fig. 3—Close-up of integrator section, which is the heart of the differential analyzer. This device performs the process of integrating one variable with respect to another variable. Above picture was taken looking down on the unit.

of the Differential Analyzer

Speed and accuracy are the familiar attributes of automatic computers. This machine applies both benefits to the solution of differential equations. For non-linear problems, the equation need not even be written. The analyzer can work right from the curve drawn on graph paper.

It is desired to solve for dV/dt, E and I (and eventually V itself) accurately to two decimal places, or within 0.01 of a unit. A shaft of the differential analyzer mechanism, pictured in close-up in Fig. 2, is assigned to the quantity dV/dt. To get the required accuracy, the machine is calibrated so that the shaft must turn 100 revolutions to register a change of one unit in the variable. Thus, one revolution of this shaft corresponds to a 0.01 unit change in dV/dt. One benefit of using a high ratio of shaft revolutions to the magnitude of the variables is that the effects of gear backlash, dimensional inaccuracies, temperature variations, etc., are minimized.

Similarly, E and I are represented on other neighboring shafts. Now that the variables are set up in the machine, the next step is to provide for the constants of the equation. This is done by means of a gear train. For the constant 0.1428, for example, a gear train is coupled to the E shaft. The gear ratio is selected so that the output shaft of the train makes 0.1428 revolution for each revolution of the E shaft. This is the method by which the multiplication of a variable quantity by a constant is achieved on the analyzer.

The I shaft also is equipped with a gear train having a ratio of output to input of 0.2258. Then, the 0.1428 E assembly and the 0.2258 I assembly are coupled to the end gears of a differential gear assembly, which performs the process of addition. The output shaft from the spider of the

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Fig. 4—Schematic of integrator. The total angular travel or number of revolutions of the wheel is equal to the integral of the variable r with respect to α, times a constant. In actual machine, the turntable is made of glass. Integrator wheel turns on jeweled bearings to prevent slip.

Fig. 5—Servo system steps up the small output torque from the integrator to a magniture sufficient to drive shafts and gears in the analyzer. One scheme sketched above uses light beams and three polaroid disks to minimize drag on integrator.

Fig. 6—Either multiplication or division can be accomplished by means of the mechanical system pictured at left on the adjoining page. At right, the system is shown schematically. The x, y and z distances are controlled by separate leadscrews.

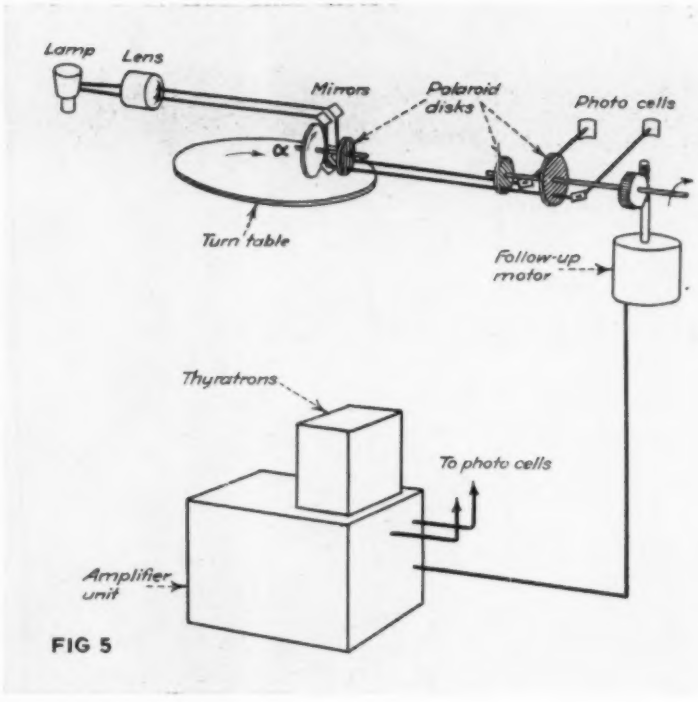


FIG 5

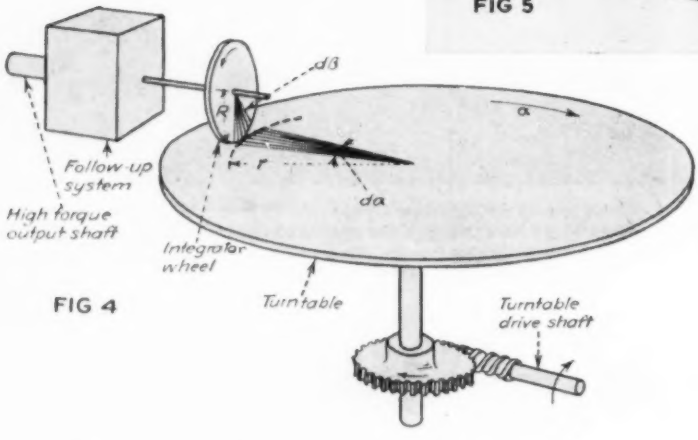


FIG 4

differential gear assembly represents the quantity dV/dt in the above equation. Actually, since the differential gear assembly has an inherent speed reduction of 0.5, which operates on both inputs, gear trains on the shafts would be selected to give two times the desired constant, so that the overall constant would be correct.

The direction of rotation of the shaft determines whether the quantity increases or decreases. If clockwise rotation is defined as positive, counter clockwise is negative. A pair of gears actually multiplies the original shaft quantity by a negative constant, since the direction of rotation is reversed. Subtraction is performed in this way, for if one of the inputs to the adders has an odd number of gear pairs in its drive it will feed negatively. In Fig. 2, the adder counts as one gear pair so there are two gear pairs in both the E and I gear trains making the drives positive in sign. But if the E gear train had one more gear pair, even if the ratio were one to one, Eq (1) would become

$$\frac{dV}{dt} = 0.2258I - 0.1428E \qquad (1A)$$

Integration

The key unit of the analyzer is the integration section, pictured in Fig. 3. This device performs the process of integrating one variable with respect to another variable. The integrating device actually does the solving of the differential equations.

To complete the solution of Eq (1), the shaft representing dV/dt is geared into the proper shaft of the integrating unit. Another shaft of the integrating unit is geared to the time shaft, and the third shaft of the integrating unit represents V. The schematic drawing in Fig. 4 shows the fundamental components of the unit. Assuming that there is no slippage, both arcs generated by the point of contact between the integrator wheel and the turntable are equal. Or,

$$R\,dB = r\,d\alpha \qquad (2)$$

Where

R = radius of wheel
r = (variable) distance from center of turntable to point of contact with integrator wheel (equivalent to integrand)
B = angular position of wheel (may be more than 360°)
α = angular position of turntable

(Note: "angular position" may be changed to "number of revolutions").

Then

$$dB = \frac{1}{R}\,r\,d\alpha$$

And, by integration

$$B = \frac{1}{R}\int r\,d\alpha \qquad (3)$$

The position of the integrator wheel can be varied to establish different values for r in Eq (3). To change the constant R, it is necessary to replace the integrator wheel with a wheel of proper diameter. In the solution of the sample equation the dV/dt shaft would control the distance r, the time shaft would control the angle α, and B would equal V. Since R is usually designed to be equal to unity, Eq (3) would then appear as

$$V = \frac{1}{1}\int \frac{dV}{dt}\,dt$$

As stated, Eq (2) is true provided

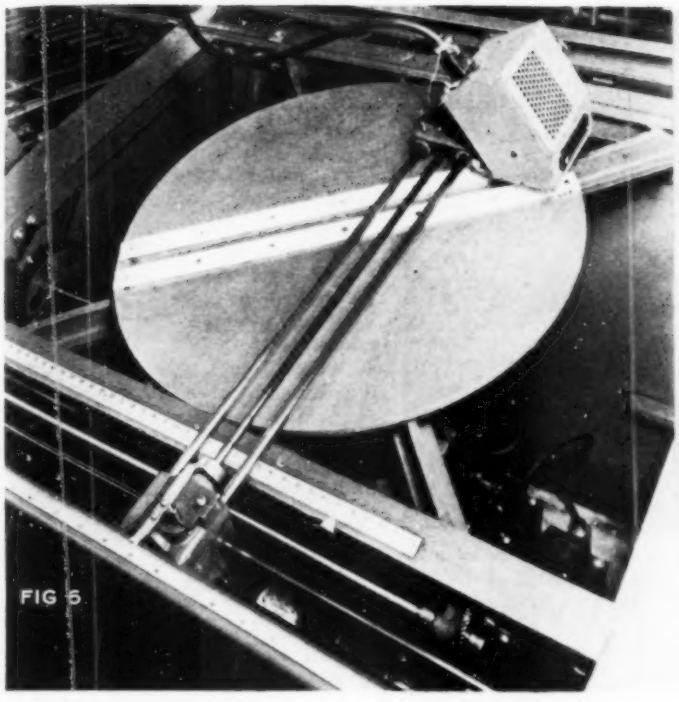
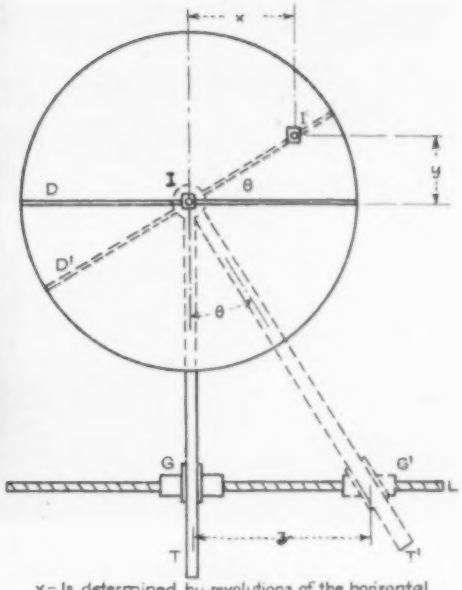


FIG 6



x – Is determined by revolutions of the horizontal lead screw H (not shown)
y – Is determined by revolutions of the vertical lead screw V (not shown)
z – Is determined by revolutions of the polar lead screw L

that there is no slipping between the integrator wheel and the turntable, which is plate glass. To prevent slipping several precautionary measures are taken. The integrator wheel is mounted in jewel bearings, as are the supports of these bearings. This design accommodates vertical motion of the wheel should not the turntable be perfectly flat. Even so, by screw adjustments, the turntable is held flat to a tolerance of 0.002 inches at its extreme 4.0 in. radius. Further, the wheel is positioned so there is no side thrust on it, all forces of contact being directed to rotate the wheel.

The integral quantity must have a high torque behind it to turn the various shafts in the machine in accordance with the equations. Such torque is not available directly from the wheel. Therefore, a special servo system is used to drive the output shaft in step with the integrator wheel. The sketch in Fig. 5 shows the elements of this system. A polaroid disk is mounted with the integrator wheel, but does not touch the turntable. The two beams of light that pass through the disk are polarized, and then pass on to two outer polaroid lenses. These outer polaroid lenses are mounted on a common shaft, and have their axes of polarization at 90 deg with each other. In a certain position the outer polaroids will polarize their individual beams of light an equal amount, and the phototubes will receive equal amounts of light. This is the balance point. No signal is sent to the amplifier and the motor does not move. But when the first polaroid lens moves with the integrator wheel, the light on the phototubes becomes unbalanced, a signal goes to the amplifiers, and the motor turns to restore the balance. A deviation of about 5 deg from balance is enough to drive the motor at full speed, so the follow up system is sensitive. It follows accurately at speeds to 1,000 rpm and above.

The distance r shown in Fig. 4 represents the value of the integrand, and may be varied over a range of ± 4.0 in. This is done by means of the threaded leadscrew, which is so threaded that the distance represents ± 64 revolutions, calibrated to hundredths of a revolution. Thus, initial conditions may be accurately set and readings taken, whenever desired, of the value of the quantity represented. The independent variable may be any quantity, although it is most commonly the variable time.

Such a latitude of variable permits multiplication of two variables by means of two integrators solving the well-known equation $uv = \int u dv + \int v du$. The two integrators work simultaneously and their outputs are added to produce uv. This type of multiplication can also be done mechanically, as shown in Fig. 6. In this arrangement the tangent bar T is clamped to the hub of a polar table and is free to slide through the bushing on the L shaft. The polar table is a circular flat plate whose only motion is about an axis perpendicular to its center, and on which is an engraved diametral straight line D at right angles to the tangent bar.

For purposes of explanation, assume a reference condition with the angle θ equal to zero ($z = 0$) and with I, the indicator, whose position is controlled by x and y at the center of the table ($x = 0 = y$). Now let x, y and z be varied so the diametral line D moves to D', and the indicator I moves to I' (on the diametral line). Now the distance from I to I' will be r where

$$r = \sqrt{x^2 + y^2}$$

and it follows that

$$x = r \cos \theta$$
$$y = r \sin \theta$$
$$z = k \tan \theta$$

It is known that

$$\sin \theta = \tan \theta \cos \theta$$

so

$$y = \frac{xz}{k}$$

or

$$x = \frac{ky}{z}$$

The leadscrew L is 9 in. from the center of the plate and is threaded at 10 revolutions to the inch, so if x, y, and z are measured in revolutions it can be seen that the constant k equals 90.

Either multiplication or division can be done with this arrangement. For

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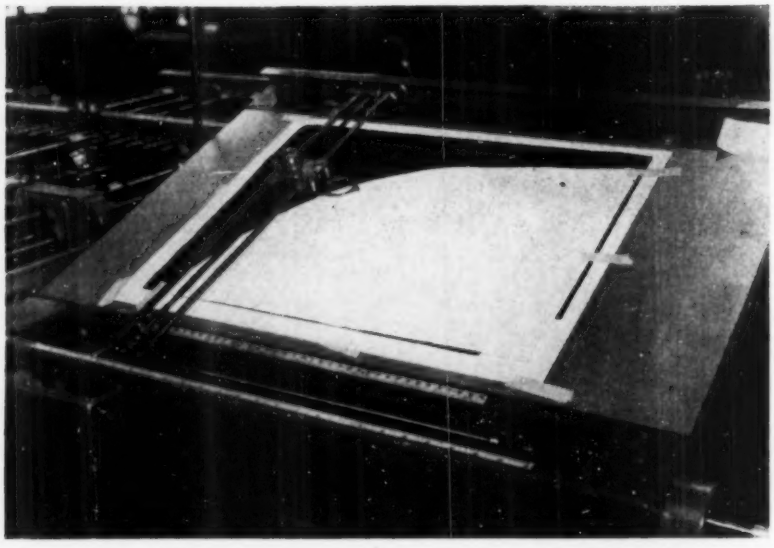


Fig. 7—Input table is used to insert non-linear functions into the machine for solution. The equation of the curve need not be established. As the tracing head is moved over the curve, the function is entered automatically. This feature is an important time-saver.

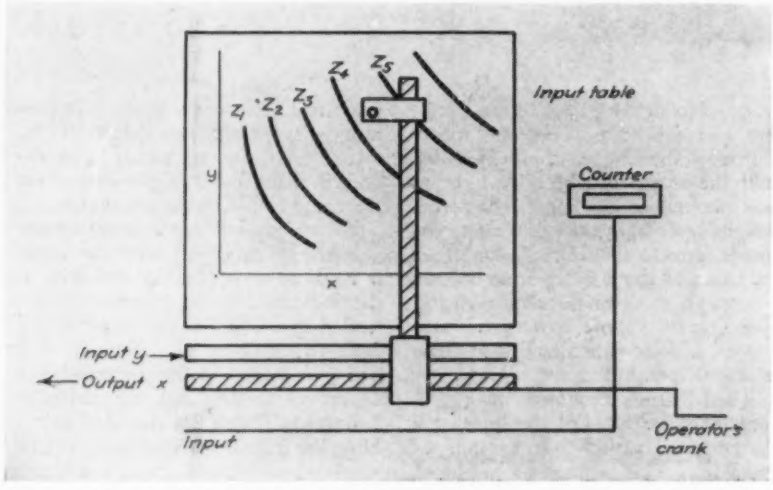


Fig. 8—Schematic of input table set up for non-linear function of two variables. The graph is a family of curves. Automatic curve followers are available for machine.

multiplying, (given x and z to find $y = xz$), the machine drives the x and z shafts and an operator varies y to keep the indicator I on the diametral line D. For division, (given y and z to find $x = y/z$), the machine drives y and z and x is controlled to keep the indicator on the line.

Insertion of Non-Linear Functions

In a problem involving transformers, one of the equations involved might try to describe the relationship between flux and magnetizing current. But such equations are complex. It is far simpler to use a graph of the relationship and insert it into the analyzer by means of an input table, such as that shown in Fig. 7. For this solution, the shaft for magnetizing current, already determined by another equation, is geared into the table to drive the bulls-eye horizontally. An operator turns a crank geared into the vertical to keep the bulls-eye on the curve (the line between white and black). This crank would, at the same time, drive the flux shaft in the machine proper. An automatic curve follower, using phototubes to detect the curve, can be employed in place of the operator. Thus the true, exact relationship between the two quantities is incorporated in the solution. Without the differential analyzer or other such computers, the solution of such equations involves laborious hand calculations, which actually employ the same general method the analyzer does but at a much slower rate.

In a more complicated case where one quantity is a function of two variables, the graph is a family of curves. For example, atmospheric drag on an aircraft is a non-linear, empirical function of velocity and altitude. A graph is made of drag (x) versus velocity (y) for various specific altitudes (z_1, z_2, z_3). As pictured in Fig. 8, the machine drives the vertical shaft (velocity); the altitude shaft drives a counter; and the operator rotates the horizontal shaft (drag) to keep the bulls-eye in the proper position, interpolating between the various altitude curves as necessary. Following a similar method, a function dependent upon the values of three variables has been generated, the graph being in the form of families of curves.

The cover plate of the input table can be removed to disclose the polar table, which is driven by a third shaft independent of the horizontal and vertical drive shafts. This polar table may be used to feed inputs into the machine if the problem incorporates polar coordinates, or to plot an output in polar coordinates. It may also be used for generating special functions and to perform a multiplication or division of one variable quantity by another variable quantity as already explained.

Solution of Equations: Presentation of Results

The engineer, having decided which equations properly describe the system and having decided how to represent the non-linear or empirical functions that appear in the equations, now decides on the accuracy necessary for a satisfactory solution. A schematic, like that in Fig. 11, of the analyzer as it is to be set up is prepared. The engineer must also observe the limits imposed by the analyzer. For example, the integrand must not be greater than ± 64 or the integrator wheel will be driven off the turntable. If he knows that this would ordinarily happen, it can be circumvented by not solving for, say,

$$v = \frac{dv}{dt}\,dt$$

but for

$$\frac{1}{2}v = \left(\frac{1}{2}\,\frac{dv}{dt}\right)dt$$

by which arrangement the leadscrew is held within range. The user must know the machine.

On the other hand, the accuracy of the integrators is lowest when the integrand is small. In such a case where, say, dv/dt ranges only between $\pm$ 1,

the equation solved might be

$$64v = \left(64 - \frac{dv}{dt}\right) dt$$

thus extending the range of the lead-screw to the more accurate regions. This manipulation, of course, also affects the accuracy of the measurements, for dv/dt at a level of one-half a revolution for a unit of dv/dt cannot be measured as accurately as when 64 revolutions are required to make a unit change. Common sense and experience must, therefore, be used throughout this important step in setting up the machine.

The engineer must then compute what the initial values of the variables are to be. In an electrical problem, for example, the initial values of the various currents, voltages and impedances must be known. In a ballistics problem, the position, the speed, and the acceleration of the bullet as it leaves the rifle must be available.

Lastly, the engineer must decide what results of the solution are important, and whether to use graphs or counters as the method of presentation. The output of the integrator sections can be fed into a plotting table, Fig. 9, to control movement of a drafting pen. The solutions to the problems are presented in graphical form. Or, numerical solutions can be obtained by coupling digit counters to the integrator output shaft.

Sample Problem

As an illustration of how the analyzer is used, consider the problem of the recoil of a machine gun while firing. It is desired to determine the effect of the strength of the recoil spring and buffers on the rate of fire. A schematic of the system is shown in Fig. 10a, where the recoiling parts of the rifle are lumped into a single mass M and the recoil spring and buffers are represented by a spring.

The fundamental equation involved in this system is that force equal mass times acceleration, which may be written as

$$F = m \frac{d^2x}{dt^2}$$

The force is made up on two components, one of which is due to the burning of the powder, F_p, the other from the recoil spring and buffers, F_x, which by definition act in opposite directions. Thus

$$F = F_p - F_x$$

The engineer now determines the nature of F_p, probably by actual firing tests on the gun. A typical plot of the variation of this force with time is shown in Fig. 10b. By choosing the types of springs and buffers to be used, a plot such as Fig. 10c can be made, although in this study there will probably be several such plots (used one at a time) for the various spring gradients, etc. to be used on successive runs.

The equations to be used are now written in their complete form as follows:

$$\frac{d^2x}{dt^2} = \frac{1}{M}\left(F_p - F_x\right)$$

$$\frac{dx}{dt} = \int \frac{d^2x}{dt^2}\, dt$$

$$x = \int \frac{dx}{dt}\, dt$$

$$F_p = f(t)$$

$$F_x = f(x)$$

and the schematic drawn as in Fig. 11.

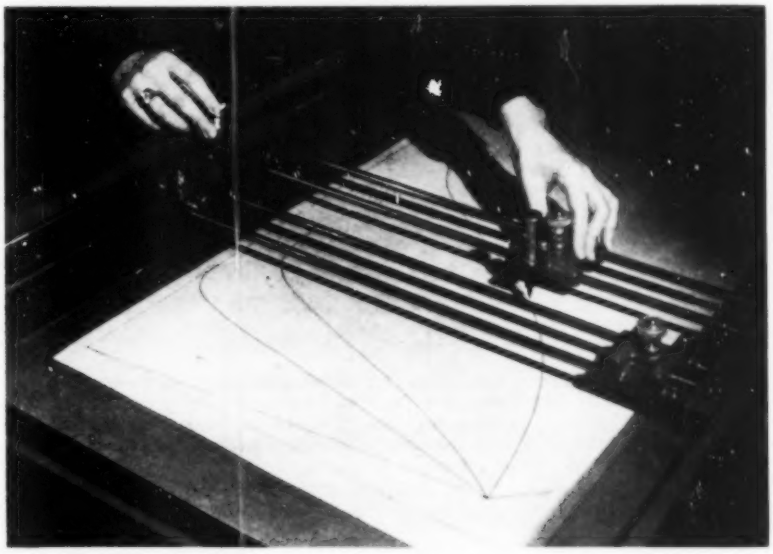


Fig. 9—Output Table. The responses of a system with several variations of components are plotted on one sheet of paper for easy comparison. The pen is driven automatically in both directions by the machine as it solves the characteristic equations of the system.

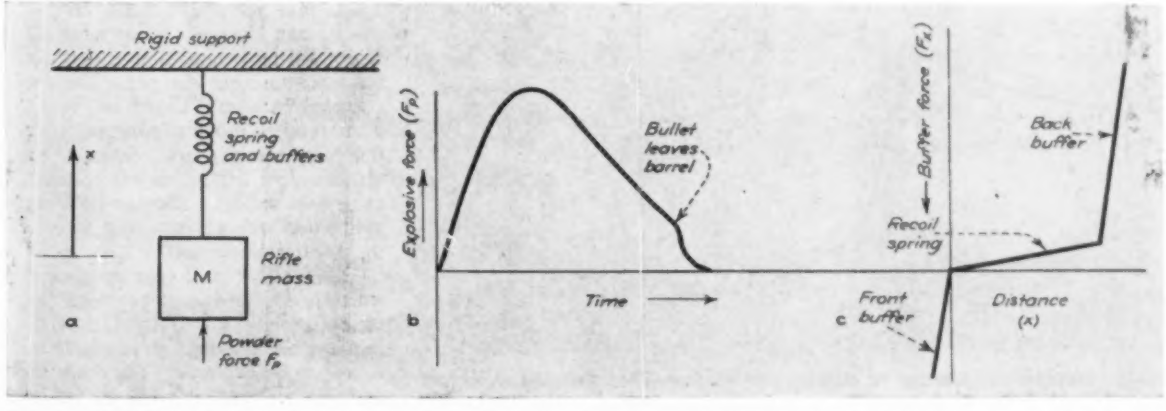


Fig. 10—Helpful sketches for visualizing sample problem described in text: (a) Schematic of machine gun system; (b) Plot of force from powder versus time; (c) Plot of spring and buffer forces. Object of the problem is to select proper recoil system.

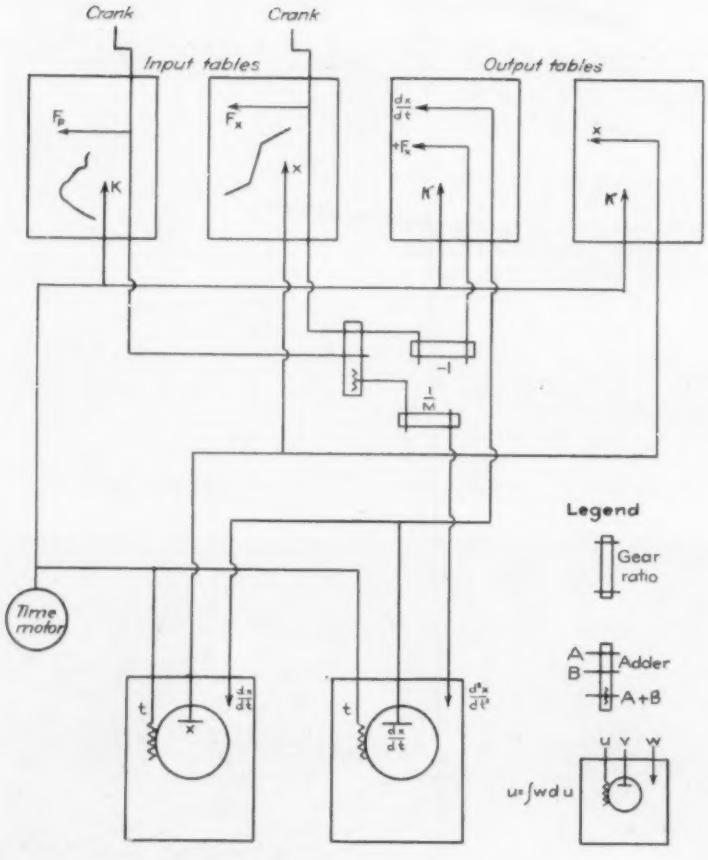


Fig. 11—Schematic of analyzer arrangement for the machine gun recoil problem. With this sketch, the flow of the problem from input tables through adding and integrating sections can be followed up to the presentation of results on the output tables. In all except the simplest problems, it is necessary to prepare sketches before solving them.

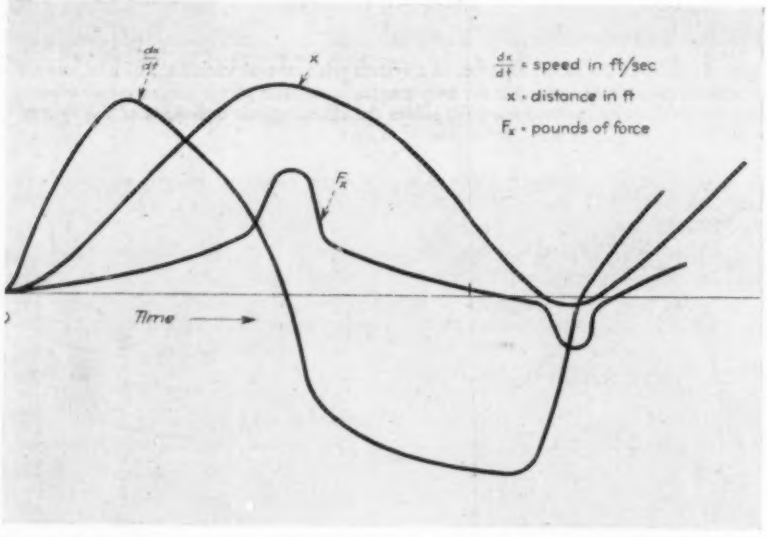


Fig. 12—Possible output curves for machine gun problem. They show the recoil position and speed of the gun during firing and also the force exerted by the recoil spring and buffer assembly. The hump in the F_x curve occurs when the gun hits the buffer. Before design of gun is complete it may be needed to try several recoil systems.

As this figure shows, the engineer has chosen to pilot dx/dt, F_x and x versus time as the results of the study and has also made the choice to represent F_x by means of a plot.

He must now compute the initial conditions. If the gun is to be fired from complete rest the initial conditions will be

$$t = 0;\ \frac{dx}{dt} = 0;\ \frac{d^2x}{dt^2} = 0;\ x = 0$$

$$F_x = 0 \qquad F_p = 0$$

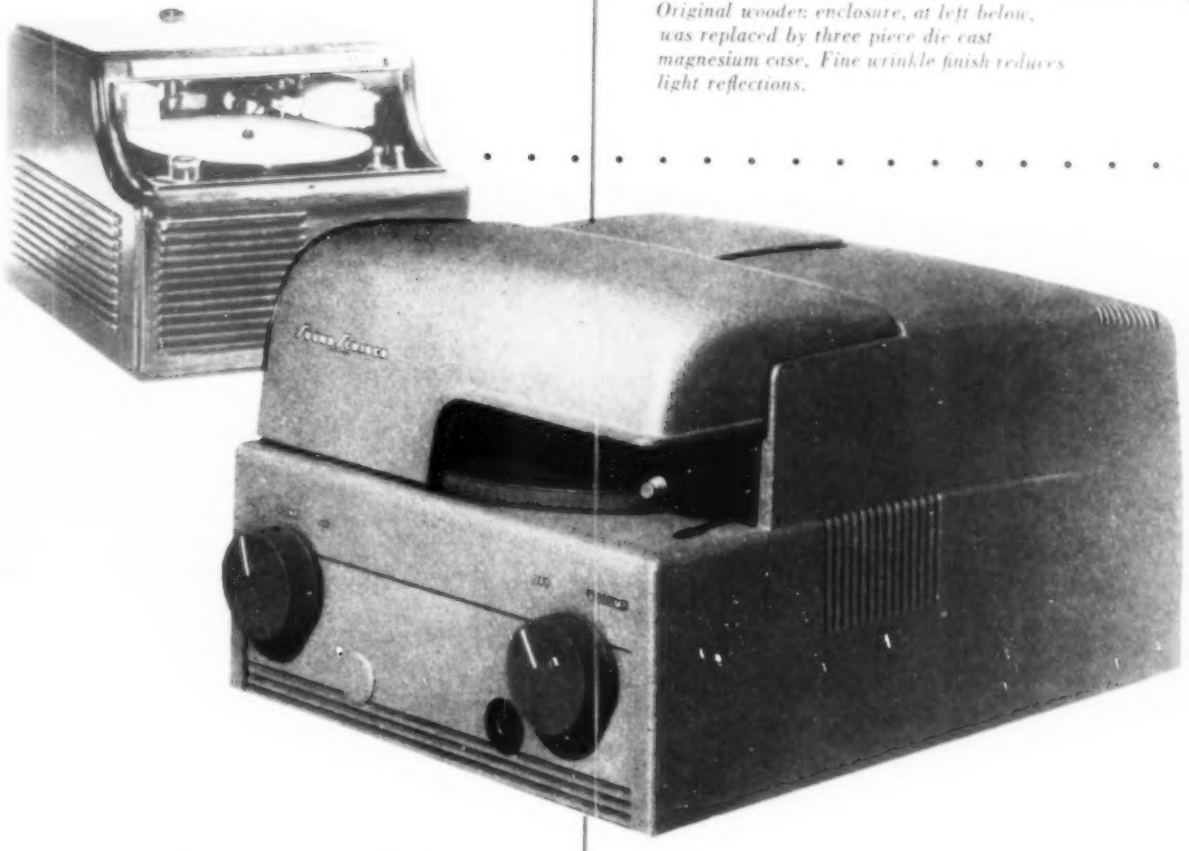
The leadscrews of the integrators and the bulls-eyes and pens are then set on zero-zero and the time motor started. This drives the F_p bulls-eye horizontally on the plot and the operator, in following the graph, cranks some F_p into the machine. The resultant movement of the d^2x/dt^2 leadscrew of the integrator causes dx/dt to increase. This will, through the other integrator, cause x to increase.

As x increases, the F_x operator, in following the F_x curve, cranks in some F_x, reducing the d^2x/dt^2 leadscrew. While this is going on the output pens will be plotting the values of dx/dt, x, F_x as they vary. Finally, as F_p falls to zero and F_x continues to rise, dx/dt will reverse its sign and the gun will move into counter-recoil. When it has reached its rest position ($x = 0$ as read from a counter), the next round will be fired, which will be represented by resetting the F_p table and again cranking over the curve. It is of interest to note that when the second round is fired the new initial condition will be

$$\frac{dx}{dt} \neq 0;\ \frac{d^2x}{dt^2} = 0;\ x = 0,\ F_p = 0;\ F_x = 0$$

Probably two or three rounds will be "fired" until the gun settles down into a steady rate of fire. When the engineer is satisfied that this has been reached, he can, by measuring the time between rounds determine the rate of fire. The machine will be stopped, the F_x plot changed to represent different spring actions and a new run made in the same manner. The output plots may be as shown in Fig. 12. These curves provide information on the performance characteristics of the recoil system. It is possible to determine how various buffer combinations will work without installing each of them and running tests.

The analyzer is already proving its worth in the solving of problems that were formerly solved by brainwork. But another big field of applications is still to be explored. These are the design and research problems which formerly were too complex to be solved mathematically.



Below is the dictating and transcribing unit designed by Raymond Spilman for the Soundscriber Corp. Original wooden enclosure, at left below, was replaced by three piece die cast magnesium case. Fine wrinkle finish reduces light reflections.

Objectives in Industrial Design

Appearance design, or industrial design, is not a purely artistic endeavor. While sense of perspective, taste and drafting ability are required, these talents are subject to restrictions. What these restrictions are and how they can be met are brought out by studies of successful products.

THE STYLING of a successful product is seldom the result of pure artistic talent, freely exercised. Before he makes his first sketch, the industrial designer is aware of the objectives set up by the sales, product engineering and production departments. His job is to give the product the most pleasing appearance possible, while working within the framework of those aims.

SALES OBJECTIVES—The sales department lists two main objectives: 1. The product must appeal to the prospective buyer; and 2. It must look better than competitive products. To meet the first aim, the industrial designer compiles data on customer preference. This information is supplied by the sales group or may be obtained on a special survey. Color is usually dictated by customer preference. Weight and size are also influenced by the same factor. Then—especially in household appliances—there must be included in the design certain refinements and convenience features that are not essential to the product's operation but do influence sales.

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The industrial designer also looks hard and long at the competitor's products, if for no other reason than to make sure that the new design will be distinctive in appearance. In addition, the conservative designer wishes to imitate to some degree the styling of a successful product and to avoid that of a slow-selling unit. A "big-seller" is a good indicator of what customers want in the way of styling.

ENGINEERING OBJECTIVES—Ordinarily, the engineering of the product mechanism is completed before appearance design is begun. It is undesirable to make changes in the arrangements of structure and components. This situation places additional restrictions on the shape of the enclosure.

Designers have found, fortunately, that the basic mechanism usually indicates its own most interesting external shape. The less "air" enclosed the better. But, in some cases the designer approaches the engineering department, requesting a change in the mechanism. At this point, negotiations begin to establish whether or not such a change is possible, and whether or not the improved appearance, increased utility or other benefits justify the cost of making the change.

Besides determining the shape of the mechanism, engineering may require the designer to include features necessary for the satisfactory operation of the machine. Examples are the provision of air vents for cooling an engine; dusttight shields for delicate mechanisms and access panels for components requiring frequent servicing. Since such features are vital to product performance, the designer has no choice but to provide for them.

PRODUCTION OBJECTIVES—The last major set of objectives come from the production group. Unless money for extensive new tooling is included in the development appropriation, production specifies exactly what process is to be used in the manufacture of the product. The production process influences styling considerably. The industrial designer who is limited to stamped parts may not have the freedom he would have if die casting or injection molding machines are available.

The production process specified actually has a compound effect on styling, because the process may decide the designer on the material. Although both sales and engineering at times call for specific materials for the enclosure, material selection is restricted most often by the existing production facilities.

Since plant investment is such a major part of manufacturing cost, the industrial designer can do little to change production aims. However, it is sometimes possible to standardize the parts for two or more products to get volume up to a point where a change of process is economically justified. For a manufacturer who wants the utmost in saleability, the stylist may recommend outside purchase of parts to permit free choice of process.

Production objectives do not stop with the choice of process. Routinely, the industrial designer is asked to provide: 1, ease of assembly for labor savings; 2, a finish that can be applied in the booths and tanks already on the production floor; 3, a minimum number of parts for materials handling and inventory economics; and 4, interchangeable parts for the same reasons.

These many objectives and restrictions make industrial design a practical science. Thus, the appearance of a product is not the result of artistic inspiration so much as a logical solution to a series of down to earth problems. This is brought out by a study of some successful, well-designed products.

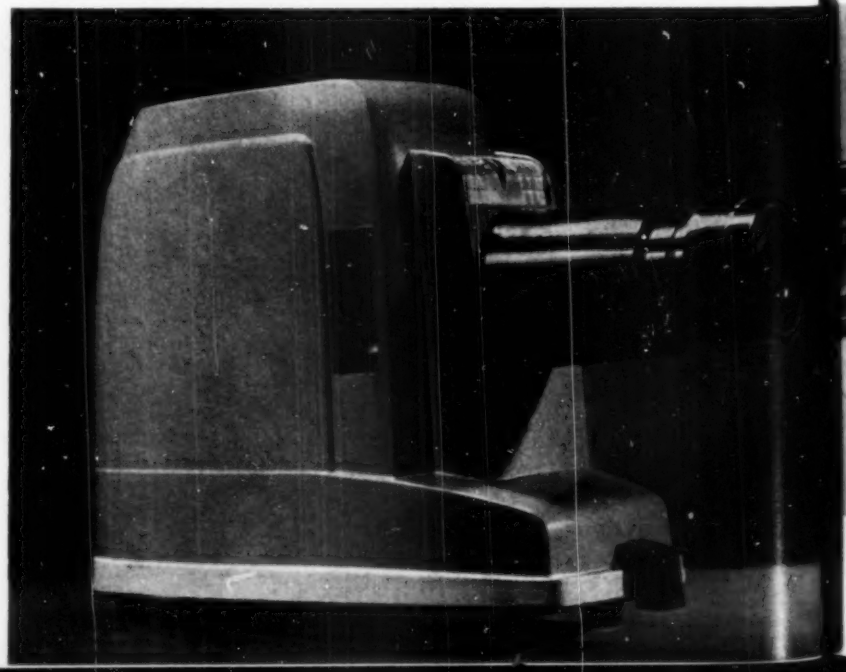
PROJECTOR

At the time design of the SVE Skyline projector, Fig. 1, was undertaken, there were perhaps 15 or 20 different makes of projectors on the market. Many camera stores stocked 10 or more of the various models. The aim was to design a machine that would stand out in a shelf or window display without violating good taste or running up cost.

The first step toward the objective was the selection of a color in the blue-green group. This color contrasted to the finishes of the other projectors, most of which were then black or brown. Also, the blue-green shade gave the impression of coolness, a desirable feature of high wattage projectors. Colors were specified to suppliers and finishers in accordance with Container Corporation of America's color chart. This was done to assure uniformity.

The aluminum die-cast case of the projector is simple, with smooth, flowing lines accentuated by semi-square

Fig. 1—Slide film projector designed by Mast Development Company for the Society of Visual Education, Inc. Blue-green color was chosen to give the impression of coolness. Transparent nameplate on side of machine has small lamp behind it, providing illumination for reading manuscript and sorting slides.



ornets. Plastic nameplates were adopted, one being transparent and the other having a reflecting undersurface. Carmine and gold insignia on the reflector nameplate added a flash of color to the otherwise plain blue-green finish. As an added sales feature, a small lamp bulb was installed behind the transparent nameplate. Thus, this nameplate doubles as a "manuscript window," which casts enough light for reading a paper or sorting slides.

Other features of the projector include a fast-acting, lever-operated mechanism for tilting the base; use of a low-priced bayonet base lamp in place of the costly prefocused lamp in previous models; and a slide changer which makes it possible to put in and remove slides from the same side of the machine.

AIR CONDITIONER

Room air conditioning units are bulky machines by nature, since even a smaller room calls for heat pumping capacity greater than most conventional household refrigerators. Large compressors, evaporators and drive motors are essential parts of the mechanisms.

The industrial designer for the new General Electric Company air conditioner, Fig. 2, had as his first objective the reduction of the apparent bulk of the machine. This was done by reducing the surface areas that are presented directly to the view of room occupants. The front panel does not rise the full height of the mechanism. Instead, the front is foreshortened in width and height. The sides and bottom of the enclosure are tapered up and in to meet the front wall. Thus, the product appears to be smaller than competitive models that actually have the same or smaller overall dimensions.

Another aim was to give the air conditioner an appearance that would harmonize with a maximum number of domestic and commercial interiors. Smooth finishes of steel and plastic in tones of beige and brown were chosen because these colors blend with the finishes of most wood furniture. Also, the colors are neutral and so do not stand out in sharp contrast to the decoration of the walls or to the colors of other furnishings in the room. The front grille work is bright brass so that the overall styling matches other household units, such as radio and television sets.

Back of the grille are three louvered disks, projecting slightly below the plastic frame that encloses the grille. These disks can be rotated independently by the finger tips to direct the cooled air all in one direction or in three different directions and at an infinite number of angles. This flexible feature was contributed by the designer.

DUPLICATING MACHINE

This project began with the desire of Ozalid, a division of General Aniline and Film Corporation, to produce a compact, movable, table model of its well established reproduction machine. The Ozalid process makes duplicate copies of any lettering or drawings inscribed on translucent paper.

The industrial designer was commissioned to give the machine an appearance that would have sales appeal, would be restful to the operator and would fit in with the environment of a business office. Since the basic mechanism was already completely engineered, the external design had to be completed with a minimum of mechanical changes. Also required was the minimizing of tooling costs because of possible low production. It was not certain what market would be found for a portable machine.

Metal was specified for the housing, Fig. 3, since the latter is used to support the mechanical structure. The enclosure follows for the most part the general outline of the mechanism, which includes a series of conveyor belts. Contours were rounded for cleanliness, rigidity, and because the flowing, rounded form has been proven to have a psychological appeal to the average person. The sides of the housing, which are the major stampings of the enclosure, are interchangeable.

The only change to the mechanism of the Ozalid machine was shifting the controls closer to the center of the end panels. This was done to present a better balance or symmetry. To make controls legible, the strongest contrast — white on black — was used. For a mechanical device of this type, legibility is more important than color appeal, which would call for pastels.

The roller, which can be seen through the front opening, is of gray rubber. This represents a change from the black roller originally specified by the mechanism designers. Product identification

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Fig. 2—Room air conditioner designed by Walter Dorwin Teague for the General Electric Company. Back of the grille are three louvered disks which can be rotated independently to provide any desired pattern of air distribution.

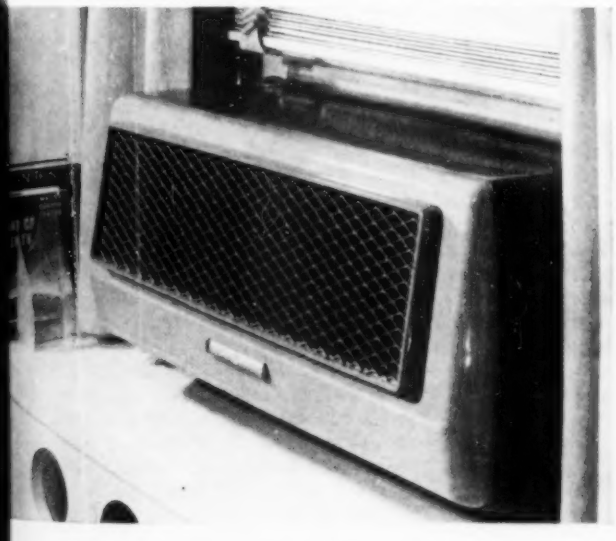

Fig. 3—Copying machine designed by Raymond Loewy Associates for Ozalid, a Division of General Analine and Film Corp. Rounded lines were suggested by outline of conveyor belt mechanism. Gray color is restful to the operator.

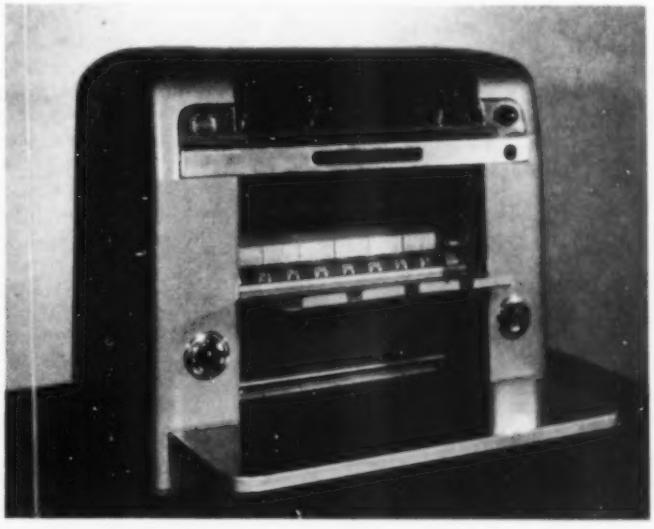

Fig. 4—Electronic tape recorder designed by the engineering department of the Webster-Chicago Corp. Reels are recessed into the drawn steel top for protection and for streamlining. Maroon hammer finish, the same color used on other products of the company, was chosen for economy.

Fig. 5—Deep well turbine pump redesigned by Henry Dreyfuss for the Byron Jackson Company. Improved appearance was accomplished with negligible change in cost because only the top and base sand castings were altered. Oil reservoir was relocated within the base for better lubrication.

is through a chrome-plated stamping with raised and polished lettering. The background is depressed and filled with green paint.

The overall color is metallic gray, which is more restful than stronger colors. This is an important factor in a machine used 8 hours and more a day by its operator. The color also blends with office equipment, such as filing cabinets and metal desks, which are now generally gray in color.

ELECTRONIC TAPE RECORDER

Appearance design of the new Webcor 210 tape recorder, made by the Webster-Chicago Corporation, was carried out under a number of limitations. The mechanical, electronic and acoustical design was not to be affected. Use of existing production tools was required. Also, the new unit was to have some resemblance to the styling of existing Webster record changers and recorders.

The shape of the recorder top, Fig. 4, was established by the desirability of recessing the tape reels for protection and to prevent the reels from dominating the overall appearance. Since the mechanical engineers had already specified that the top was to be drawn of commercially available steels, the depth of the wells and the height of the escutcheons were limited. Here is an example of the restrictions under which the industrial designer must operate. If the designer were free to specify a die casting of zinc, magnesium or aluminum, the top could have been designed with more extreme variations in contour. The resulting appearance might have added interest, but cost would be considerably more.

The width and depth of the recorder were also determined to some extent by the tooling and material used. A certain amount of the surface area surrounding the reel wells was allowed to give rigidity to the drawn top. The height of the case was established by the speaker diameter and by the size of the amplifier chassis. Proportions of the latter are generous for ease of manufacture, servicing, and tube replacement.

Maroon hammer was the finish selected for the recorder top. This is the same finish used on other Webster-Chicago products. The sales department felt that consumers associate this finish with the Webster name and the production department wanted the economy of one color in the spray booth. For conservative styling, it was decided to use no more than two colors. The fabric and leatherette selected for the case match the maroon hammer finish closely. The second color is the natural polished finish of the brass locks and hinges. This finish is attractive, and provides economy and durability. The control knobs and the escutcheon are in the same two colors.

At this stage of the design, the recorder case was found to be below the cost objective. This enabled the designer to include a lucite escutcheon with three dimensional letterings and an indirectly lighted trade mark emblem.

PUMP

The Byron Jackson Company's deep well turbine pump, Fig. 5, is used in agriculture and industry. Since in many installations the pump is in full view of passersby, it was desired to give it a distinctive and attractive appearance. Cost was not to be increased by the redesign.

The change in styling was confined to the top and base of the pump unit. These were given smooth, rounded lines for appearance and for ease of cleaning. The form of the top casting was tapered to match the motor shell and provide overall continuity of shape. The motor is standard, and was not involved in the redesign. Because both the top and bottom sections were sand castings, the redesign had little effect on cost. Lifting lugs and hold down bolts were made integral with the castings.

The color of the pump is gray. This

Fig. 6—Electric range designed by Raymond Loewy Associates for Frigidaire Division of General Motors Corp. Functional design of oven doors is outstanding appearance feature of this range. Doors are thicker at the top to provide greater insulation where oven heat is most intense.

Fig. 7—Cabinet fan designed by the engineering department of the Chicago Electric Mfg. Co. Cabinet is of brown phenolic plastic, which was selected chiefly for economy. Simple symmetry of design makes it possible to mold cabinet in two identical halves, using a single cavity mold.

is a popular industrial color and affords a good contrast with green fields when the pump is used for irrigation.

The lubrication system of the pump was substantially improved in the redesign. Originally, the oil reservoir was a tank hung on the outside of the pump. The viscosity of the oil varied with the outside temperature. Now, the oil reservoir is cast on an integral part of the base and is surrounded by the water passages of the pump. The temperature of the oil is kept near that of the water and rate of oil flow is less dependent on weather conditions.

ELECTRIC RANGE

As with other household appliances, styling of the new Frigidaire electric range, Fig. 6, was a critical consideration because it must appeal to women. At the same time, the industrial designer had to observe the standard width and height dimensions adopted by the industry.

A distinctive feature of the new range is the shape of the oven doors and the location of the door handles. The frontal area of the doors is not flat, but slopes outward so the doors are thicker at the top than at the bottom. Thus, additional insulation is provided at the upper portion of the oven where heat is greatest. The handles extend above the tops of the doors so that they can be grasped even when the doors are open full. In most ranges, the door handles are hidden from sight when the doors are opened and there is a tendency for the user to touch the hot doors to get them closed. While the doors are the outstanding factors in the appearance of the range, their design is purely functional.

The industrial designer was not free to choose color. Continuing surveys, made by Frigidaire's sales department indicate that the great majority of buyers wants white, which looks good in all types of kitchens.

The front panel containing the burner controls is slanted slightly, for visibility. Oven controls and timer are placed up on the backsplasher and to the right away from the burners. Here the controls can be reached conveniently without the danger of burns.

A 38 in. fluorescent lamp runs the entire length of the stove. Further illumination is provided by individual lamps behind each of the plastic control dials. The dial light is switched on only when the associated unit is in operation. The controls are graved metallic blue to match the timer dial on the backsplasher. Panel beneath the fluorescent lamp is of glass with a textured gold backing. Timer dial, pilot light indicators and convenience outlets are all molded in a single piece of clear plastic which is plated and painted on the reverse side.

In previous models, the storage drawer was fabricated from several stamped pieces over a bottom frame of steel channels. The new range has the drawer made as a one-piece drawing. Fabrication costs are considerably less. Also, since no bottom frame is required, the depth of the drawer has been increased to afford 15 per cent greater storage capacity.

CABINET FAN

Material selection was a prime factor in the appearance design of the fan pictured in Fig. 7, made by the Chicago Electric Manufacturing Company. A molded plastic was the choice over metal and wood. A drawn metal cabinet would involve restriction as to shape, greater tooling costs and finishing operations. A metal housing would also tend to accentuate fan noises. The use of wood would require even more costly fabrication and finishing.

The lines of the plastic cabinet are smooth and exhibit simple symmetry. This shape was adopted so that the entire cabinet could be made in a single-cavity mold. The front and back halves of the cabinet are identical. The cabinet measures 20 in. high, 23 in. wide and 11 in. deep. Each half requires 9 lb of phenolic plastic.

ELECTRONIC STENCIL MAKER

The "Stenofax," Fig. 8, manufactured by Times Facsimile Corp, is used to make stencils directly from printed or pictorial matter. When a page of copy is placed on the copying drum, the machine scans it electronically and transmits the impulses to a spark cutting device. The latter cuts a high fidelity plastic stencil that can be used on standard duplicating machines.

Since this is not a high production item, the industrial designer was limited to the use of standard extrusions and simple stampings for the case. The unit is classed as a business machine, so it is finished in gray with stainless steel draw pulls and trim and a dark gray kick base. Nameplates are of etched metal, which is inexpensive even for low volume products.

The electronic and mechanical sections of the machine are installed in the two deep drawers in the base cabinet and can be easily removed for servicing.

WALL HEATER AND FAN

The "Wall-aire" in Fig. 9 is a combination fan, heater, and hair dryer. The design was developed to convey the illusion of being built-in rather than protruding into the room. A gently tapered and sloping design contour was produced to house the motor, fan, heating element, hair drying hood, drying rack, and controls. This contour, in addition, directs the hot or cold air currents downward on the room occupant.

The hood section, when not in use, is completely enclosed in the die cast hood frame. The frame can be shifted to transform the fan into a hair dryer. All controls are recessed. Because of the problem of heat dissipation and since a wall mounted fixture requires rigidity and strength, the designer chose a drawn steel housing with a die cast aluminum grille and hood frame. The switch area is shrouded with a molded plastic switchplate. The plastic plate affords added protection against shock to persons with moist hands and serves also for product identification.

Two contrasting neutral colors are used: cream for the main housing and pearl gray for the grille and hood section. These colors harmonize with the many color schemes used in bathrooms, where the unit is usually installed. The fabric originally chosen for the hood was replaced with a plastic-coated kraft paper. This is accordian pleated and makes a strong tear-and puncture-resistant hood that is easily cleaned and safe from mildew.

Fig. 8—Stenofax machine designed by Henry Dreyfuss for the Times Facsimile Corp. Feature of the design is the two deep drawers in the base cabinet which contain the mechanical and electronic sections of the machines. The drawers can be pulled out when necessary for servicing.

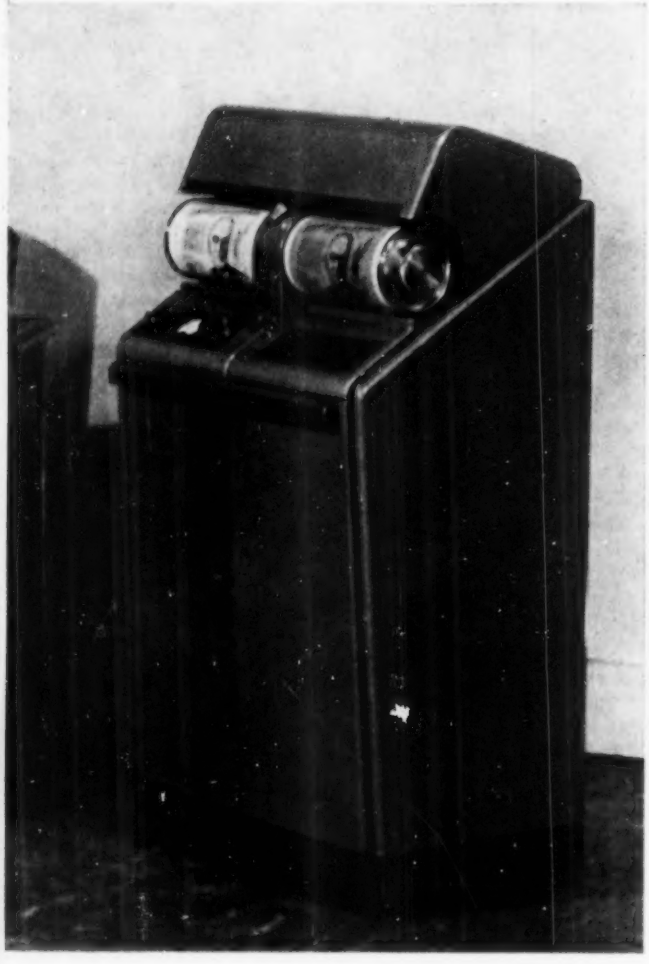

Fig. 9—Combination wall fan and heater designed by Charles E. Jones for Fresh'nd Aire Co., a division of Cory Corp. When accordion-pleated hood is opened, the heater doubles as a hair dryer. Housing is tapered to give unit a "built-in" appearance and to direct air flow downward.

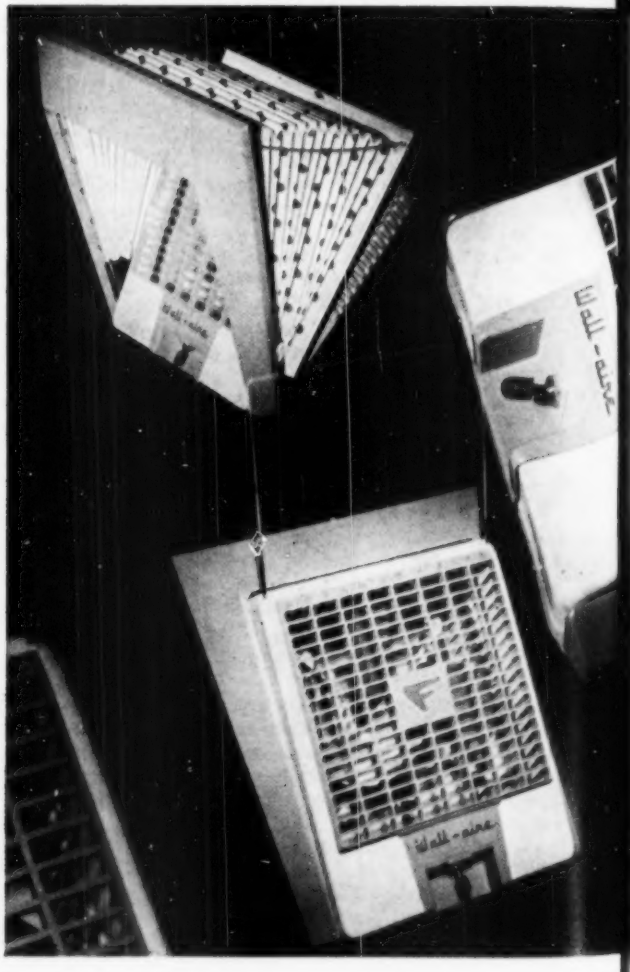

Fig. 10—Calculating machine designed by Walter Dorwin Teague for National Cash Register Co. Housing is fitted about mechanical structure with a minimum of enclosed air space. Operating keys are pastel for less contrast.

Fig. 11—Vacuum cleaner designed by Henry Dreyfuss for the Hoover Co. Top is of blue plastic for light weight and simplified assembly. Since colors are molded in, no finishing is required save filling letters of name with paint.

BUSINESS MACHINES

The calculating machine, Fig. 10, is an example of a complex device which is simply housed. The housing was designed to follow the outlines of the mechanical structure closely with minimum of wasted space. The contours are smooth to permit easy cleaning. Both keyboards are tightly shielded and as far as possible all mechanisms are covered to prevent the entry of dust.

Again, gray is used on the housing in conformance with the accepted coloring of business machines. The keyboard colors were selected to minimize fatigue. These machines are used by skilled operators throughout the entire working day and eyestrain becomes a problem. The old-fashioned machine with its color scheme of black, bright red and bright blue required the maximum eye accommodation and hence fatigue. The pastel colors used in the keyboards here are all of approximately the same value although easily distinguishable. Thus accommodation is eased and eyestrain greatly reduced.

Although of a different shade, the gray of business machines is seen again on the Mimeograph Duplicator, Fig. 13. The finish is a smooth hammerloid, easy to keep clean, pleasant to the touch and more consistent in production than a single tone smooth finish.

Portions of the machine that are frequently handled are finished in chrome, adding some highlights to the machine. For additional contrast, certain important small handles and levers are molded in bright vermilion plastic.

VACUUM CLEANER

In high production consumer items, like the Hoover Model 62 vacuum cleaner in Fig. 11, attractive appearance, light weight and ease of assembly are the principal objectives of the industrial designer. Use of plastic helps to achieve all three aims. Tenite top requires no finishing after molding, other then filling the trade name impressions with paint. The cleaner is equipped with a vinyl furniture guard and an acrylic light lens. The base is an aluminum die casting.

The basic shape of the housing is determined by the arrangement of the motor and the mechanisms that drive the fan and the brush. Blue and cream color combination was chosen on the basis of consumer research, the reports from salesmen on housewife preference, and the effect of the color schemes of competitive products on their sales.

DICTATING MACHINE

In many cases, the industrial designer actually betters the objectives set for him by the production engineers. At the time the redesign of the Soundscriber, pictured on the first page of this article, was begun, it was decided to change from a wood cabinet to a die cast case of zinc, aluminum or magnesium. The assembly was to be limited to five or six pieces. However, by a combination of engineering and styling compromises, the present case assembly consists of only one major and two minor parts, die cast in magnesium. The fewer number of pieces gives the effect of simplicity and compactness, emphasizing the small size of the unit. The cost of the die cast case is substantially less than that of the wood.

A second design and engineering problem was size and location of the controls. All controls vital to customer operation of the unit are placed on a single panel at the front of the machine. Color of the machine is brown-gray, which blends well with wooden office furniture and the blue-gray and green-grays used on many business machines. The fine wrinkle finish was specified to avoid light reflections.

POWER WHEEL

The Bearcat Power Wheel, Fig. 12 is a self-contained drive unit for installation on bicycles and light three-wheel vehicles either as original equipment or in conversion. Two-cycle engine, transmission, brakes, disk-type automatic clutch and springs are assembled as a unit.

The industrial designer had the problems of keeping the units light in weight and providing adequate cooling and accessibility. To save weight, the projection of the housing was minimized. The compactness of the design had the effect of retarding cooling. To remedy this, the housing was provided with an air scoop at the front. Then, the bottom was left open for full air flow and for escape of exhaust gases.

Lower panel is detachable for servicing. The simplest means for securing this panel would be to provide studs welded to the bottom of the gas tank. But if studs were ever broken off in service, it would be hazardous to re-weld the studs to the gas tank. Accordingly, special clips were devised for mounting the cover on the motor frame.

Since the power unit is for installation on many types of commercial and pleasure vehicles, the color was chosen to blend with a variety of color schemes and to appeal to all tastes. The finish is a light metallic gray with cream and gold trim.

ICE CREAM FREEZER

The "Handyfreeze," Fig. 14, a departure from conventional ice cream makers in that the tub is of cellulose acetate in place of the conventional metal or wood. The use of plastic made possible the seamless, one-piece design, which is the distinctive feature of the product's appearance. Production people called for a tapered tub to permit nesting in storage.

Plastic was asked for by the sales department for light weight, lower cost and for appearance that is more compatable with modern kitchen equipment. Kitchen colors—white with a slight mixture of blue—were chosen for harmony and to give a functional impression of coolness. The motor housing is a standard shape that is used on other appliances. Rubber ring covers the rough edge at the top of the tub, acts as a friction surface to prevent the unclamped motor from creeping and serves to dampen vibration.

Fig. 14—One-quart ice cream freezer designed by the engineering department of Chicago Electric Mfg. Co. Plastic replaces the conventional wood or metal tub. Although shape is simple, the new material makes this product's appearance distinctive.

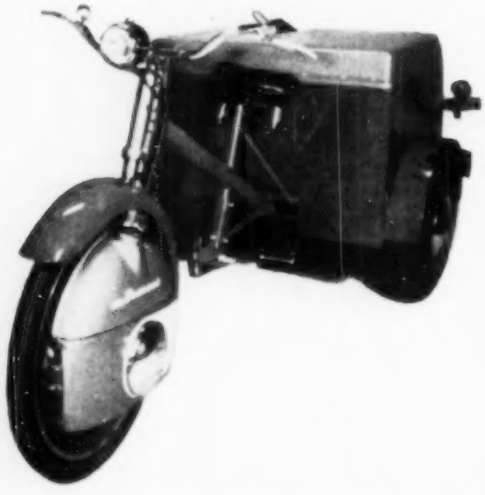

Fig. 12—Bearcat power wheel attachment designed by Raymond Loewy Associates for American Brake Shoe Co. To minimize weight, wheel housing is made as small as internal mechanisms permit. Compact enclosure retards cooling, so air scoop and open bottom are provided.

Fig. 13—Mimeograph Duplicator designed by Walter Dorwin Teague for A. B. Dick Corp. The mechanism dictates the shape of the machine because a good portion of the working parts must be open to the view of the operator. Red plastic handles and chromium fixtures add contrast to the gray finish of the machine.

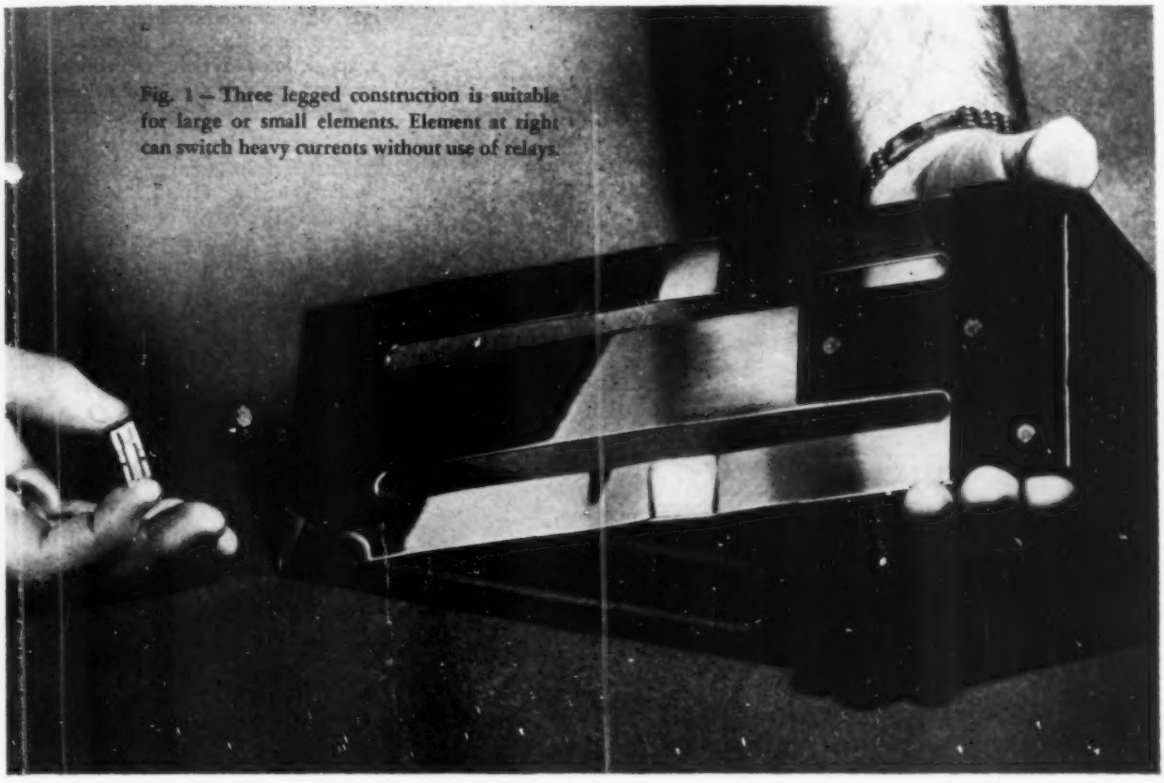

Fig. 1 — Three legged construction is suitable for large or small elements. Element at right can switch heavy currents without use of relays.

Closer Temperature Differentials in

Bimetallic Thermostats

A spread of only two degrees between "on" and "off" actions is attainable with a new bimetallic element. This three-legged element has a life expectancy of one million operations.

P. R. LEE

Westinghouse Electric Corporation, Mansfield, Ohio

ONE MILLION OPERATIONS without failure and a temperature differential of only two degrees are made possible by development of a three-legged, inherently snap-acting bimetallic element. Ordinary bimetal life is usually one tenth as much, and temperature differential is usually ten times as great.

The new element, Fig. 1, is a rectangular-shaped bimetallic piece that has two longitudinal cut-out slots. These divide the element into three sections or legs, with the two end zones common to all three legs. One end of the center leg and its corresponding end-zone are restricted from motion by a flat T-shaped steel blade rivetted to the bimetallic element. Ribs or flanges on these sections of the element will usually function as well. The two outer legs of the element are crimped so that a series of waves are formed in the metal. Crimping shortens the length of the two outer legs with respect to the center leg and creates a bimetallic unit possessing inherent snap-action. The greater the depth and number of these crimps, the greater is the snap action. This eliminates use of separate springs and over-center toggles for positive abrupt movement.

An understanding of the operation of conventional bimetallic thermostat elements aids in the evaluation of this construction. Thermostat elements are made in many and varied designs. But all can be classified under one or the other of the following categories: (1) The creep type, in which the contacts are opened or closed slowly; and, (2) the snap-action type, in which the contacts move abruptly. Each type has distinct advantages not possessed by the other. The creep type is not subject to vibration and shock so fatigue failures are less frequent. The snap-action thermostat has

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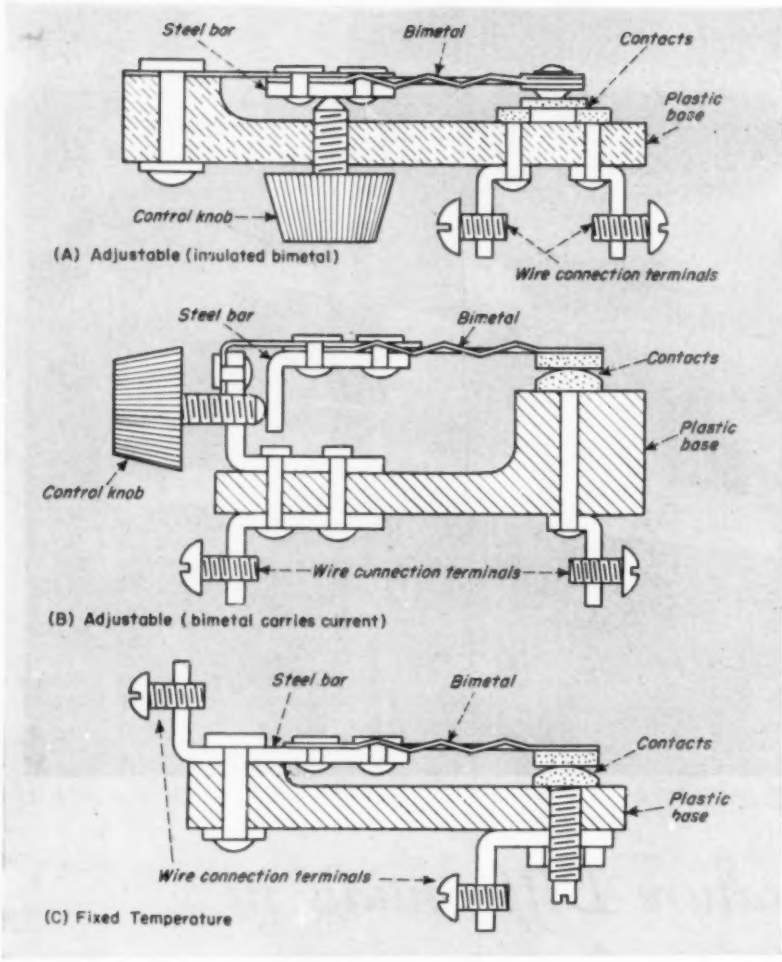

Fig. 2—Basic types of thermostat construction. Note that in adjustable thermostats the bimetallic element may be insulated or may be used to carry current to terminals.

the advantage of long contact life.

Snap-acting thermostats are produced in two forms, employing either inherently snap-acting bimetals or composite snap-acting structures. The first form has a bimetalic member that is snap-acting in itself. The disk type has been the prominent design in this group. The second form usually has a slow acting bimetal that actuates a separate spring-toggle mechanism.

Ordinarily, disk-type thermostats are cheaper than the composite structure, occupy less space, and have very positive contact travel. Construction is more rugged, so they are less affected by shock and vibration. But, disk types operate on inherently wide temperature differentials, have short life and high thermal inertia. Design of the three-legged thermostat combines the features of the disk-type plus the good points of both the composite snap-acting structure and the creep-type unit.

The combination of metals used has an important bearing on the performance of the bimetallic element. Combinations that have flexivity constants high enough to yield considerable thermal deflection also have correspondingly high internal stresses. The latter lead to short life. At the same time, such bimetallic elements have the advantage of operating on close temperature differentials. It is evident, therefore, that the designer must balance the length of service life desired against the number of degrees spread betwen the "on" and "off" temperatures. The smaller is the spread, the shorter the life.

As the thickness of a three-legged element is increased, more energy is developed with higher internal stresses resulting. These conditions shorten life of the element, but make possible operation on smaller temperature differentials. This behavior is the opposite of that of a conventional bimetallic element in which an increase in thickness causes a reduction in deflection. Hardness is a desirable property of a bimetallic element, because it lengthens life and improves the snap action. Where the bimetallic element doubles as a current-carrying part, ohmic resistivity is of importance.

In general, the most active bimetallic material in the greatest practical thickness is chosen for the three-legged element. The active combinations are those that deflect the most for a given temperature differential. Of course, in any choice of materials, temperature stability must be considered. If the characteristics of the bimetallic combination change with temperature, the operating accuracy of the thermostat will be poor.

Crimping of the stamped element is done on a special forming machine. The machine consists of a pair of adjustable spur gears that have projecting teeth over a small portion of their periphery. Pitch diameter for each tooth is adjustable, as is center-to-center distance between the two gears. Proper adjustment makes the gears engage just within their outside diameters instead of at their pitch diameters. The bimetallic piece is placed between these two gears, which are revolved slowly so that no more than two teeth of the first gear and one tooth of the second gear engage the bimetal simultaneously. This creates a bending or forming action on the bimetal that does not stretch the material.

Three conventional schemes for incorporating the basic three-legged element in a complete operating thermostat are pictured in Fig. 2. In the first, a flat T-shaped bar is rigidly attached to a phenolic base through a hinge spring. The free end of the bimetallic element has an insulated bridging contact that engages two stationary contacts on the phenolic base. A temperature adjusting screw engages the rigid bar. The T-shaped bar rigidly clamps one end of the center strip to its corresponding end zone.

In another design, the T-shaped bar is formed with a 90 deg angle so as to engage a temperature-adjusting screw, which has an axis in the horizontal position. The hinge spring is also formed at 90 deg and is attached to a mounting bracket riveted to the phenolic base. One movable contact is welded to the free end of the bimetallic element, which engages one stationary contact attached to the phenolic base. The bimetallic element carries current in this design.

The third design is the type usually used on fixed temperature thermostats. No hinge spring is used and the bimetallic element is attached directly to the phenolic base. The stationary contact is on the end of the threaded

screw so the opening temperature may be adjusted at the factory. Here again the bimetallic element carries current.

Design of a Fixed Temperature Thermostat

This type of thermostat is accurately temperature-calibrated in the factory, and then permanently sealed or locked at this setting. It operates at this one temperature only and cannot be readjusted in the field.

One of the main problems in thermostat design is to convert the desired temperature limits into "free-link" values. An uncovered and unmounted bimetallic element that is not joined to a linkage system reacts at a given temperature, known as free-link temperature. But when the element is incorporated in a thermostat, it reacts at a slightly higher temperature.

If the desired closing-temperature limits in degrees F are T_{C1} to T_{C2} in which T_{C2} is bigger than T_{C1}; and if the desired opening temperature limits are T_{O1} to T_{O2} in which T_{O2} is bigger than T_{O1}; then the minimum free-link closing temperature should be $T_{C1} - 2$. The maximum free-link closing temperature should be $T_{C2} - \frac{T_{C2} - T_{C1}}{3} - 2$.

The minimum free-link opening temperature should be $T_{O2} + K_1$, in which the value of K_1 varies from 5 to 40. The value chosen for K_1 depends on the temperature differential specified for the thermostat. This differential may be as low as 2 F or as high as 100 F. The maximum free-link opening temperature should be $(T_{O2} + K_1 + K_2$, in which K_2 varies from 20 to 75 deg, again depending on the final thermostat differential.

As an example, assume that a thermostat is required for a coffee maker. Tests indicate the final thermostat must snap within the following limits:

Open: 200 to 210 F
close: 150 to 160 F

Then

$T_{C1} = 150$ $\quad T_{O1} = 200$
$T_{C2} = 160$ $\quad T_{O2} = 210$

The minimum free-link closing temperature equals $150 - 2 = 148$ F, and the maximum free-link closing temperature equals $160 - \frac{160 - 150}{3} - 2 =$ 155 F, approximately. The actual differential of the final thermostat will vary between 40 and 60 F, or an average of 50 F. Therefore, the constant K_1 is about 25 F. Minimum free-link opening temperature equals 210 + 25 or 235, and because the average final thermostat differential is 50 F, K_2 is also about 50 F. Maximum free-link opening temperature is 235 + 50 or 285 F. From these calculations, snap temperatures of the bare bimetallic unit, usually called the free-link temperatures, are as follows:

Closed 148 to 155 F
Open 235 to 285 F

When such a bimetallic unit is assembled in a complete thermostat, the thermostat will operate to the original specification of 200-210 F for opening and 150 to 160 F for closing.

Adjustable Temperature Thermostat

Adjustable thermostats do not have a factory sealed temperature calibration. Provision is made so the customer can readily change the operating temperature of the thermostat within certain predetermined limits.

Free-link temperatures are calculated in similar fashion. Assume that the desired closing temperature limits on low are T_{L1} to T_{L2}, and that desired closing temperatures on high are T_{H1} to T_{H2}. With a maximum maintained differential of T_D, the maximum free-link closing temperature should be $T_{L1} - K_3$. The value of K_3 may vary from about 20 to 50 F, depending on the temperature range from low to high. Spreads from 30 to 100 F are normally required.

The minimum free-link closing temperature should be as close as possible to the maximum free-link closing temperature. Usually it is from 20 to 50 F below the maximum free-link closing temperature.

The minimum free-link opening temperature is $T_{H2} + T_D + K_3$, and again the maximum free-link opening temperature should be as close as possible to this—usually from 20 to 50 F above it.

By way of illustration, an adjustable thermostat may be needed for a water heater, in which the thermostat must snap within the following limits: closing temperature at extreme low setting is 85 to 95 F; closing temperature at extreme high setting is 140 to 150 F; maximum maintained differential is 15 F. Then, T_{L1} is 85; T_{H1} is 140; T_{L2} is 95; T_{H2} is 150; and T_D is 15. The thermostat can be adjusted to close at any temperature over a range of 45 to 65 degrees. Therefore, the constant K_3 should be about 30 F., and the maximum free link closing temperature will be 85 minus 30, or 55 degrees.

Because this is a narrow temperature range thermostat, the minimum free-link closing temperature can be 20 below the maximum free-link closing temperature.

The minimum free-link closing temperature is 55 minus 20, or 35. The minimum free-link opening temperature is 150 + 15 + 30, or 195. The tolerance on the free-link opening temperature can be the same as the tolerance on the free-link closing temperature (20). Therefore, the maximum free-link opening temperature equals 195 + 20, or 215. The actual free-link temperatures are 35 to 55 F for closing and 195 to 215 F for opening.

If a bimetallic unit made to snap at these temperatures is placed in a complete thermostat, the thermostat will operate within the temperature limits of the original specifications.

In Fig. 3 is shown the characteristic relationship of temperature differential vs temperature range. Note that the temperature differential is not absolutely constant. But the actual variation in differential can be very small if the thermostat is properly designed. There is an inherent tendency for the differential to be a maximum near the medium temperature and to reduce to a minimum at both the extreme low and high settings. With some production variations and with improperly designed thermostats, it is possible to obtain other characteristics in temperature differentials. Thus it is possible to have the minimum differential at either low or high settings.

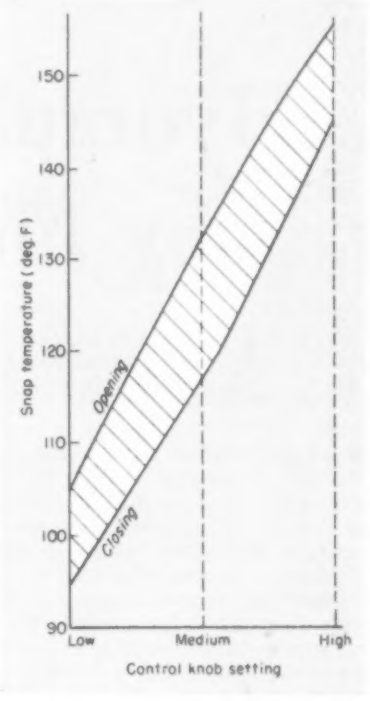

Fig. 3—Temperature differential of an adjustable thermostat at various control knob settings. The differential is not absolutely constant over the complete range. Widest variation is at medium setting.

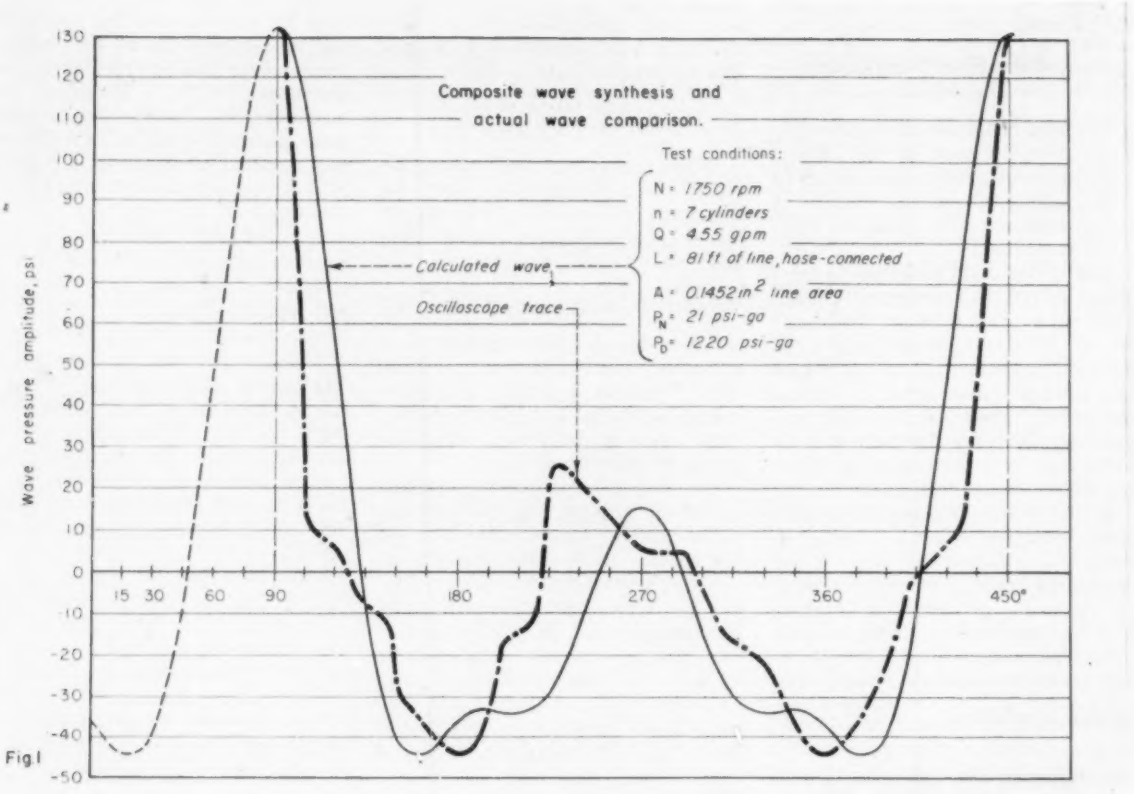

Fig 1

Hydraulic Noise Reduction by Fluid Conditioning

G. W. LOUTHAN
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THE MAJOR CONTRIBUTORS to hydraulic system deterioration are port pressure waves of which noise is the outward token. The more severe the amplitude and pressure change rate of port waves, the greater is their contribution to system deterioration.

Air dissolved or entrained in the fluid of a hydraulic system greatly increases the violence of port waves. Therefore, the fluid must be properly conditioned and system components properly designed to keep the air content of the oil low as possible if minimum system deterioration and low noise level is to be maintained.

To apply to design the principles of noise suppression wisely, it is necessary to have a full understanding of the development of port waves and how they are affected by air in the fluid.

Development of Port Waves

These pressure waves can be generated by any type of pump. They are rapid fluctuations in line pressure above and below the mean discharge pressure. In piston type pumps, pressure waves are produced in the pump when a cylinder full of oil at low inlet pressure is abruptly connected to the high mean pressure of the system. At this time, the mildly elastic fluid surges back into the cylinder and causes a sudden pressure drop in the discharge line. The momentum of the fluid causes compression in the cylinder; the fluid rebounds as a spring causing a sudden surge of pressure and completes a full sinusoidal type pressure wave. In multi-cylinder pumps these individual waves are combined to produce a wave pattern, Fig. 1, that is more violent and complex than the sinusoidal pattern.

Oil-Air Mixtures

A proper study of oil/air mixtures in relation to hydraulic noise must distinguish between several kinds and degrees of association of the two substances. The distinct conditions are:

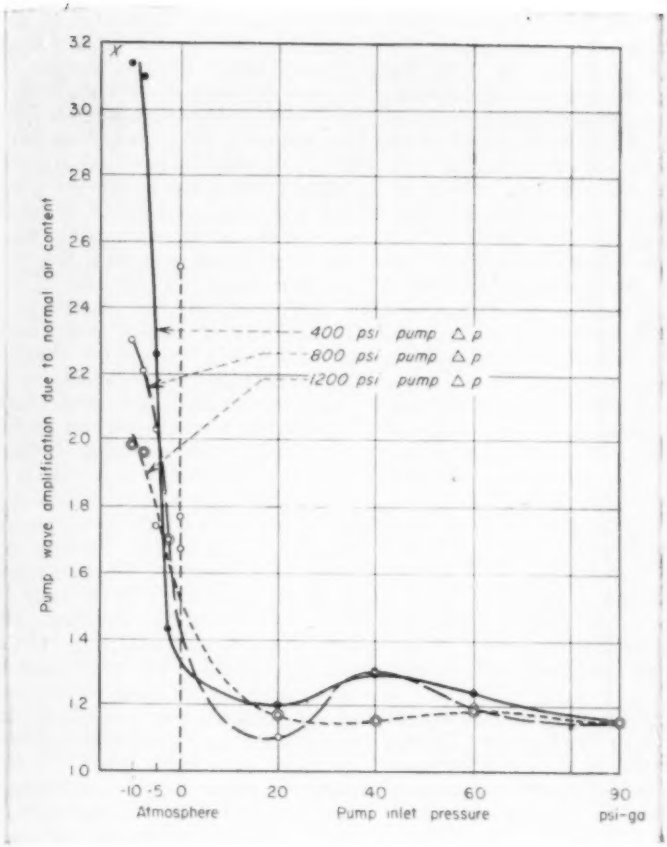


Fig. 1—Although the cam driven pistons of a hydraulic pump follow a sine wave motion, complexities in pump mechanics complicate the actual port wave.

TABLE I

P_D psi-ga	P_N psi-ga	Nominal Cavitation Coefficient, C_e					
		$x=$ 0.001	0.005	0.01	0.02	0.03	0.05
400	0	1.203	1.803	2.342	3.16	3.80	4.85
400	20	1.213	1.833	2.39	3.23	3.90	4.96
400	40	1.225	1.87	2.448	3.32	4.00	5.10
400	60	1.236	1.908	2.505	3.40	4.11	5.24
400	90	1.257	1.975	2.606	3.55	4.29	5.48
800	20	1.109	1.467	1.816	2.37	2.81	3.54
1200	20	1.073	1.326	1.587	2.01	2.36	2.93
1500	20	1.059	1.267	1.485	1.85	2.15	2.65
2000	20	1.044	1.203	1.379	1.67	1.92	2.34
2500	20	1.035	1.165	1.31	1.56	1.77	2.14
3000	20	1.029	1.139	1.262	1.48	1.67	1.99

Fig. 2—Wave amplification factors plotted opposite inlet pressure for three conditions of pump pressure increase.

Keep dissolved air from separating out of the fluid by using a pressurized pump inlet. Third in a series of three articles on hydraulic noise.

(1) Entrained air in large bubbles, say d > 0.330 in. Here air and oil are essentially separate, with the air coarsely and unevenly distributed. This condition causes violent pump cavitation.

(2) Entrained but dispersed air, with no sizable bubbles, often with no visible ones. This is the normally accepted state at pump inlet, obtainable by careful tank design and tank pressurization to minimize bubble growth between tank and pump.

(3) Oil saturated with dissolved air, only. This is difficult to obtain with rapid circulation of a limited quantity of oil, but a nearly feathered pump has a close approximation to this condition at its inlet.

(4) An unsaturated solution of air in oil. With the reasonable assumption of saturation in the tank at all times, raising the pressure of withdrawn oil will cause a subsaturated condition. Hence, this state is restricted to the discharge or high-pressure portion of the system, unless a pump inlet booster is used.

Effects of Entrained Air

If a pump cylinder contains a volume fraction (x) of free air and ($1 - x$) of oil, when it is ported to the discharge, the equivalent volume of oil exposed is

$$(V_{exp.}) = (V_s + V_c)$$

$$= \left[(1 - x) + \frac{K'}{P_D - P_N} \bullet x \right]$$

where

V_s = sweep volume of pump piston (cu in)
V_c = clearance volume of each cylinder (cu in)
K' = adiabatic bulk modulus of liquid elasticity psi. Determined experimentally to be 180,000 psi
P_N = pump mean inlet pressure psi
P_D = pump mean discharge pressure psi

which implies a theoretical amplification of basic port wave (P_e) amounting to

$$\frac{P'_e}{P_e} = \sqrt{1 + \frac{K}{P_D - P_N} - 1}\, x = C_e \qquad (1)$$

where (C_e) is the cavitation coefficient or amplification factor.

As shown in the second article of this series,

$$P_e = \pm 2.06 \sqrt{\frac{(P_D^2 - P_N^2)\, Q}{C' A}} \qquad (2)$$

where:

C' = 37,000 in per sec wave velocity experimentally for tubing
Q = pump displacement GPM
A = section area discharge line, sq. in.

To show its major trends, the function for (C_e) has been evaluated and tabulated in Table I for an arbitrary range of conditions.

Since the void fraction (x) can be only roughly conjectured for a given case, the exact values of (C_e) have less practical application than their manner of change with (P_D), (P_N) and (x). It should be noted that the tabulated values of (C_e) are upper limits, because the air was assumed to be concentrated. If the air were dispersed throughout the cylinder oil, the action would be milder, though to a degree not readily determined. However, during the filling of the cylinder the oil averages a quarter-turn of the

pump while incurring a centripetal acceleration ranging from 100 to 400 G's which would tend to separate the air from the oil.

The accuracy of the theoretical values of Table I is supported by the results of a series of oil pumping tests conducted in the Lockheed Aircraft Mechanical Research Department. The results of these tests are summarized in Fig. 2. One half of the tests were run with the system filled with thoroughly degassed oil in which the free air fraction (x) was reduced to a minimum. The other half of the test was conducted with the system filled with oil saturated with air at room temperature and pressure (75 F and 14.4 psi).

Three curves of constant (ΔP) show the ratio by which measured pressure amplitudes for the saturated oil exceeded those for oil with no air. Table I and Fig. 2 may be connected by these observations:

(a) Consider the net pump rise (ΔP) alone first. From Table I it is evident that increasing (ΔP) or ($P_D - P_N$) should give a reduction in (C_e), even though (x) increases slightly. On the other hand, since (ΔP) is substantially equal to the pressure drop through the system throttle, increasing it will tend to raise (x), especially for the lower values of (P_N). The degree to which (x) at the pump inlet increases with (ΔP) is largely a function of oil tank performance as an air separator. Some tendency toward such an increase appears in Fig. 1 but the dominant effect at high and low (P_N) was an improvement with rising (ΔP).

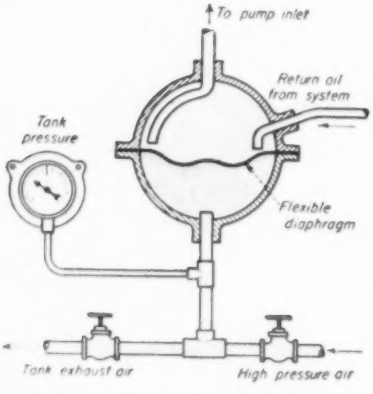


Fig. 3—Diagram of reservoir used at Lockheed Mechanical Research Department to control the pump inlet pressure.

(b) The sinuosities in the curves for values of $P_N > 20$ psig imply a perplexing variation of (x) either in magnitude or in dispersion of air at pump inlet. It is believed that both variations were involved here.

Circulation was rapid and oil reached the reservoir, Fig. 3, in less than 4 seconds after passing the throttle. The slight tendency toward resolution in the cooling coil was more than offset by the falling pressure gradient and about the only relevant effect of the cooling coil was reduction of foaming. Thus, practically all air released by throttling reached the reservoir. The humps in the curves may be interpreted in terms of the amount and distribution of air reaching the reservoir and what happened to it therein.

Although little velocity/pressure conversion could occur downstream of the throttle, local pressures were low enough to allow air release even when the back-pressure was well above saturation. This has been observed often experimentally and the curves confirm it in a general way. Moreover, as the back-pressure is increased with no change in ΔP across throttle, the decreasing amount of released air assumes a more and more finely divided form.

The first tests of each series were made with zero inlet pressure. Throttle air release was so great that the reservoir was entirely unable to separate the air, resulting in artificially high values of (C_e) which are indicated but discarded in drawing the curves. Inlet pressure of 20 psi-ga was next imposed and a practical optimum resulted; air release was brought within the reservoir's separating power, due both to reduction in amount and to either retention or regain of sufficient bubble size that the intake depth was but lightly penetrated. With inlet pressure at 40 psi, the further reduction of air release was much less than the initial step 0 to 20 psig, but the bubble size was much reduced, so new separation difficulties arose in the reservoir and the pump inlet x actually increased. The other two steps in P_N show the effect of successive reductions in air volume reaching the reservoir and pump.

(d) For high values of P_N all three curves converge toward an apparent asymptote of $C_e = 1.10 - 1.15$, instead of decreasing separately as per Table I. The reason for this is that any closed system with limited oil quantity will recirculate a certain amount of entrained air in bubbles too small for tank separation.

Potential Effects of Dissolved Air

Entrained air, however, finely divided, is still separated air. In contrast, dissolved air is dispersed on a molecular scale and cannot change the oil's acoustic behavior in any perceptible degree. The importance of dissolved air is that part of it will be released under suitable changes of pressure or temperature. The promptitude with which air can enter or leave the dissolved state, when stimulated by a transient pressure change, is clearly a key factor in appraising the hydraulic noise potential of dissolved air. With rapidly alternating pressure as generated in an axial flow piston type pump the net rate of air separation exceeds the solution rate. This allows the creation and growth of bubbles in a body of oil which is at a high enough mean pressure to be considered greatly subsaturated. Such instability of air content is what makes heavy pump waves dangerous beyond their own magnitude; they may permit the formation of voids in the fluids which lead to local collapse pressure surges far in excess of anything the pump could generate. If such voids form and collapse within the body of liquid, these shock pressures are heavily damped in traversing even a small distance and the main result is an increase in noise level. If any part of the system assumes resonance, the resultant standing wave encourages the formation of sizable voids at the points of maximum pressure change. Since this is often a surface, there exists the same possibilities for cavitation erosion as often appear in hydraulic turbines, pumps and propellers. Valves, elbows and other fittings in the line may become pitted and a fine suspension of metallic dust may appear in the originally clean oil, presenting a serious hazard to system operation.

Cavitation caused by air dissolved in hydraulic fluid is considered unlikely if entrained air is kept to a minimum at the pump inlet. Although it can be induced in laboratory set ups, the long lines and attached equipment of commercial systems tend to damp the pump waves enough to keep excessively low pressure waves from reaching the pump inlet. However, once line cavitation begins, it tends to persist, because the void itself allows a great increase in energy diversion and aids in the developments of more voids. This forms a chain reaction that is hard to stop.

Methods to Reduce Effect of Air

In view of the improbability of establishing a completely air free hydraulic system, steps should be taken in the design of system components to suppress the evolution of dissolved air to air bubbles and to prevent the entrapment of bubbles in large enough voids to cause excessive line cavitation. Among these considerations should be the possibility of deaerating

Fig. 4—Circuit diagram of hydraulic system used in a commercial type airplane. Air pressure (inlet at upper right) maintains constant force on hydraulic fluid in effort to keep desolved air from collecting in bubbles at the pump inlet.

the oil and to filling the system with care to minimize the danger of air entrainment and absorption.

In the experiments conducted at Lockheed, the following method of deaerating the fluid and filling the system was used.

1. Before the system was filled with oil, a vacuum of 1 in. Hg absolute was sealed in the system and all leaks were corrected until leakage was reduced to .15 in Hg pressure rise per hour.

2. The oil was heated, by throttling, to about 150 F. Apart from the induced change in specific saturation air weight, the main purpose here was to reduce the oil viscosity to assist in bubble clearance.

3. The pressure on the air side of the reservoir diaphragm, Fig. 3, was reduced and the system oil drained as completely as possible into the reservoir, leaving a sizable free surface over the liquid.

4. Pressure in the air space of reservoir and system was reduced to about 0.1 in. Hg absolute and the degassing of the system was observed by means of a bubble-bottle until gassing was reduced to one bubble every 10 seconds.

5. A pressure of about 1 in. Hg absolute was held inside the hydraulic pump piston case by a vacuum pump connected to the case drain through a suitable trap.

6. The reservoir diaphragm support pressure was increased and oil was thereby raised into the system circuit, while the pump was rotated by hand. The application of the vacuum was shifted to the highest point in the system and was valved out when the circuit was filled.

This method of degassing may be too complicated for field maintenance practice but it can be used in the initial filling process at the factory. Compensation for leakage losses can be maintained by a leakage make up pump incorporated right into the circuit.

The reservoir should be designed to prevent foaming and as much distance as possible should be maintained between return line and pump inlet. Tank free surface should be large enough to permit time for most bubbles to surface before re-entrainment can occur.

For any stated tank size and oil circulation rate, there is a critical bubble size below which re-entrainment is a practical certainty. This critical bubble size may be computed as follows:

Disregarding the relative density of the air, the appropriate Stokes relation for buoyant and viscous forces reduces to,

$$d_c = \sqrt{\frac{18Fv}{g}} \qquad (3)$$

where

d_c = critical bubble diameter
F = terminal rising velocity
v = oil's kinematic viscosity

If V is put equal to the mean suction approach velocity based upon tank free-surface area, a major fraction of bubbles of d_c or smaller size will never reach the surface. This is apart from local velocities near tank fittings. In any well-designed tank, such velocities have negligible effect at points well below the surface. Example:

For the test reservoir, no free surface is assumed, but the horizontal plane at the suction entry was used.

$Q = 4.55$ gpm and $A = 75$ sq in

and with the oil temperature at 68 F

$v = 0.0325$ in.^{2}/sec.

$$F = \frac{4.55 \times 231}{60 \times 75} = 0.233 \text{ in. per sec.}$$

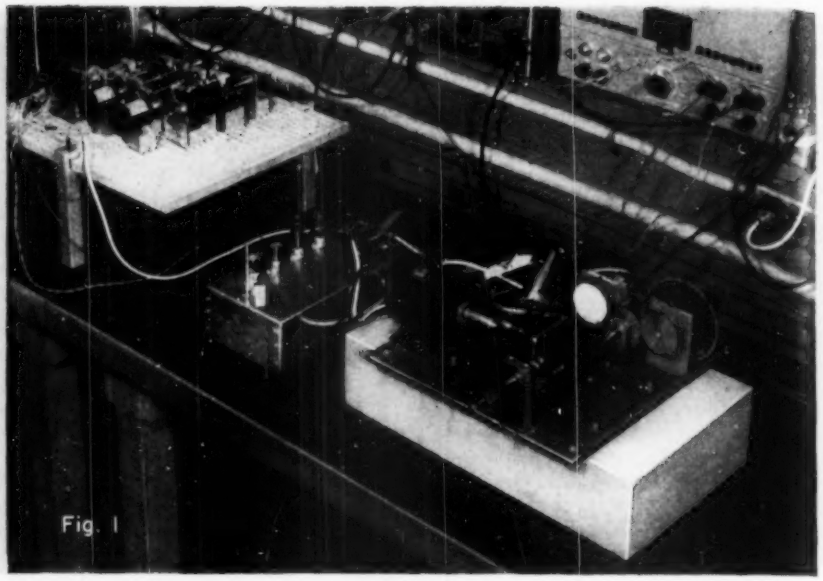
$d_c = 0.019$ in.

It must be remembered that air in the system only amplifies port waves. The main source of hydraulic noise is in the uncorrected pump or motor.

Fig. 1—Testing models of an electrical servomechanism. By use of logarithmic analysis, servos can be stabilized before they reach this stage.

Fig. 2—Schematic and block diagrams of simple proportional servomechanism. If system is stable, rotation of load duplicates exactly the movement of the input shaft.

Fig. 3—Stability can be analyzed from curves. System is stable when a line drawn from the point of intersection of the upper curve with the zero axis meets the corresponding lower curve at point above the —180 deg abscissa.



Logarithmic Analysis

NORMAN ALPERT

Project Manager,
W. L. Maxson Corporation

BECAUSE OF THE NUMBER of variables involved, control engineers must usually resort to cut and try in designing electrical servomechanisms. But costly trial and error techniques are steadily being replaced by mathematical methods. One of the most promising of these methods uses logarithms to test stability.

An example of a simple proportional servomechanism is given in Fig. 2a. The object of this system is to cause the load to follow precisely and promptly any rotation of the remote input shaft. Under initial conditions, the contact fingers of both potentiometers are in the same position electrically. Their output voltages balance so that there is zero signal on the amplifier.

Whenever the input shaft (θ_i) is moved to a new position, a voltage difference appears across the input to the amplifier. This amplified signal applies voltage to a motor which rotates a load shaft (θ_o). Simultaneously, the potentiometer that turns with the load reduces the voltage difference applied to the amplifier input until $\theta_o = \theta_i$. At this point, the voltage across the amplifier input terminals again is reduced to zero and the motor stops turning. A block diagram of this system is shown in Fig. 2b, where the error E is a maximum at the start and reduces to zero when $\theta_i = \theta_o$. In short, the operation of a proportional servo is independent of variations in calibration, gain or circuit parameters since the actuating quantity is a function only of the difference between the input and output functions. As a result, when that difference is zero, the input and output will correspond.

Causes of Instability

Even this simple servo can present instability problems as a result of excessive time lags in the system, together with sufficient gain. This instability will manifest itself in "hunting" or self-oscillation of the closed loop system at some sinusoidal frequency determined by the loop parameters.

Theoretically, a simple proportional servo should show no evidence of instability since the output quantity is always subtracted from the input. However, in practical servo systems, time lags in the amplifiers, motors, and associated equipment are inevitable. Therefore, the load may continue to rotate even after the initial error has been reduced to zero. This continued rotation sets up a negative error; after the load has stopped rotating in the positive direction, the negative error will cause the load to be driven again in the reverse direction. In an unstable system, the load will see-saw back and forth to reach the point of electrical zero—or zero error—but each time overshooting the mark. This is the condition known as hunting. It should be noted that if the input quantity, θ_i, were removed from such an unstable servomechanism, the device would be functioning as a regenerative oscillator by virtue of the feedback loop between output and input.

These features can be given a more quantitative aspect at this point by introduction of the transfer function analysis of servomechanisms. With this scheme, it is possible to test a servomechanism mathematically to determine whether or not it will be stable in operation. From Fig. 2b, it is seen that, vectorially:

$$E = \theta_i - \theta_o$$

Now the closed loop response of a servomechanism is defined as the ratio of the output to the input, so

$$\text{Response} = \frac{\theta_o}{\theta_i}$$

After replacing θ_i by $E + \theta_o$, this becomes:

$$\frac{\theta_o}{\theta_i} = \frac{\theta_o}{E + \theta_o}$$

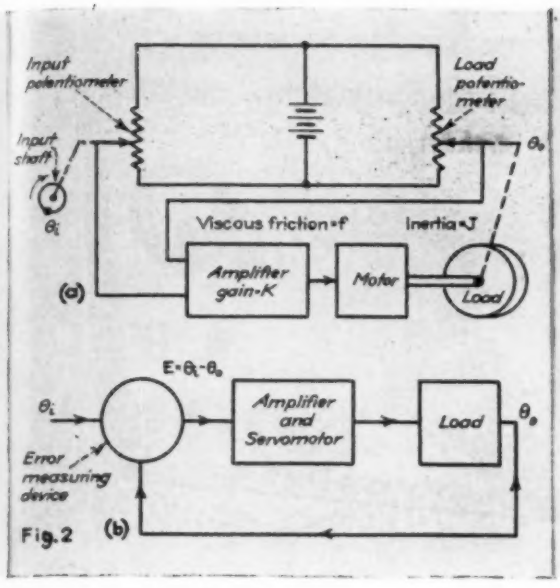


Fig. 2

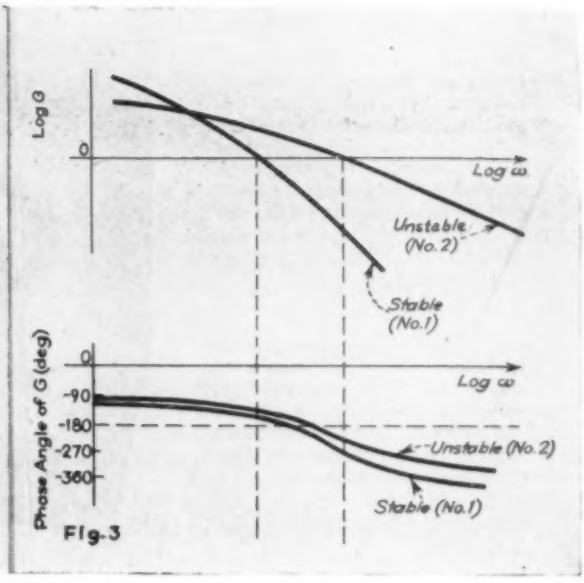


Fig. 3

# of Servo Stability

Use of logarithms gives a fast answer to the question asked in the design of any servomechanism: Will the system hunt? The system can now be tested analytically for stability before it leaves the drawing board.

Dividing numerator and denominator by E, produces:

$$\frac{\theta_o}{\theta_i} = \frac{\frac{\theta_o}{E}}{1 + \frac{\theta_o}{E}}$$

If the feedback loop is now opened, the error is just the input quantity θ_i or:

$$E = \theta_i$$

The open loop response of the servo is, therefore, simply the output quantity divided by the input quantity or θ_o/E. This term is given the symbol $G(j\omega)$ and is also known as the transfer function of the servo with the feedback loop open. The previously obtained closed loop response can now be rewritten as:

$$\frac{\theta_o}{\theta_i} = \frac{\frac{\theta_o}{E}}{1 + \frac{\theta_o}{E}} = \frac{G(j\omega)}{1 + G(j\omega)}$$

The transfer function of the proportional servo illustrated in Fig. 2 can be expressed as:

$$G(j\omega) = \frac{\theta_o}{E} = \frac{K}{j\omega(f + j\omega J)}$$

K = amplifier gain
f = viscous friction coefficient
J = moment of inertia (load and motor)
ω = $(2\pi) \times$ frequency

The following is further defined

$$\psi = \frac{f}{2\sqrt{JK}} = \text{damping ratio}$$

$$E_{ss} = \frac{f\,\Omega}{K} = \text{steady state angular error for constant velocity input, } \Omega.$$

From the above it can be seen that a servo system can be made more stable by increasing the viscous friction since the damping ratio is increased as the friction is increased. This method has some disadvantages however. One is that the steady state velocity error, E_{ss} is increased (since E_{ss} varies directly as friction) and another is that the power consumed in overcoming friction is increased.

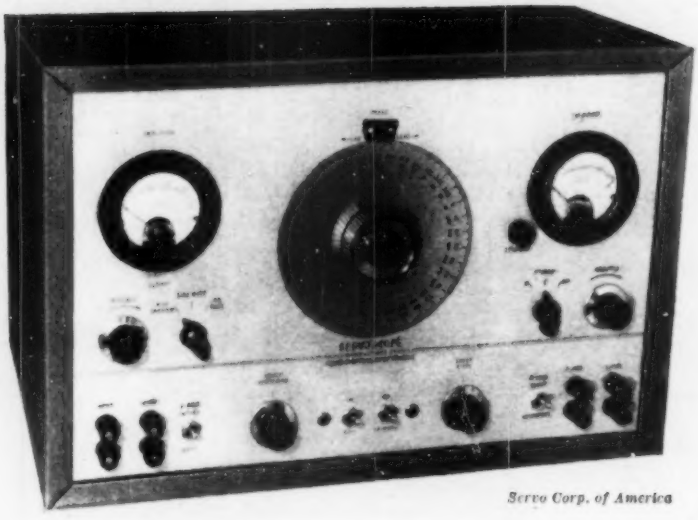
Tests for Stability

There are several criteria available to the servomechanisms engineer for examining the stability conditions which exist in a given servo. The well known Nyquist criteria can be employed with the aid of a graphical plot of the open circuit transfer function in the complex plane. Or if desired, the closed loop transient term can be examined by the Hurwitz criteria, which involves the use of determinants.

One of the main inconveniences of the Nyquist plot is that it is not a simple matter to obtain the graphical plot of the new transfer function from the original one after the inclusion of a stabilizing device. The Hurwitz criteria, while a simple and accurate means for determining whether or not stability exists, does not tell how close to stability a servo system really is. Adequate descriptions of both the Nyquist and Hurwitz criteria may be found in the technical literature.

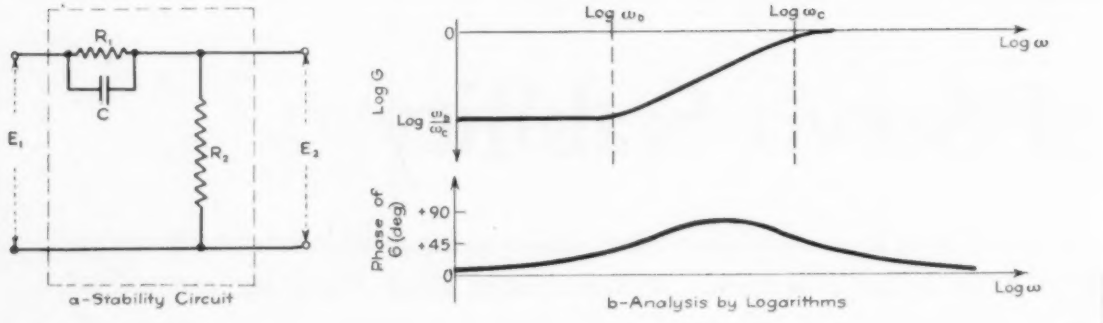
There is now available another accurate means of testing stability. This method employs logarithmic analysis and has the added advantage of simplicity. In Fig. 3, graphs of log G vs log ω and of the phase angle of G vs log ω are plotted on rectangular coordinates. These curves can be obtained by either theoretical calculations or by

Fig. 4—This device measures magnitude and phase angle of transfer function. If model of servo is available, logarithmic curves can be plotted from readings obtained with this instrument. By this means, the designer can determine rapidly whether or not the servo will hunt.



Servo Corp. of America

Fig. 5—Part A shows schematic of phase-lead circuit for stabilizing servo. Part B gives curves for evaluating the transfer function of this network. Note that the phase angle is always positive, hence the name phase-lead network.



actual measurement of the open loop response of the servo on a servo analyzer, such as that pictured in Fig. 4. This contains electronic circuits for gaging the strength of the input and output voltages and the phase difference between them.

It can be seen from the plot in Fig. 3 that a servo having the characteristic curves labeled No. 1 is stable when the loop is closed. This is so because the phase of G corresponding to the condition for $\log G = 0$ is considerably less than —180 deg. On the other hand, the servo corresponding to the No. 2 curves is unstable when the loop is closed, since the phase of G is greater than —180 deg. for $\log G = 0$. The amount by which the phase of G is less than —180 deg at the condition of $\log G = 0$ is known as the phase margin. It is good practice to provide a phase margin of about 40 to 60 degrees.

The logarithmic method provides a simple means of testing the effects of stabilization devices on the performance of a servomechanism. The new overall transfer function can be obtained readily by algebraically adding the coordinates of the original transfer function to the stabilization transfer function. In this respect, it may be preferable to the Nyquist criteria for certain types of stabilization problems.

Stabilizing Means

There are three major categories into which stability devices for servomechanisms may be placed.

1. Adjustment of gain.
2. Phase lead networks in cascade.
3. Anti-hunt feedback loop.

The first category has inherent disadvantages, since making a servo system more stable by decreasing the gain will correspondingly increase the steady state velocity error.

A common stabilization arrangement is to insert a phase lead network in cascade and thus change the overall loop transfer function so that an adequate phase margin is provided. One such network is shown in Fig. 5. The transfer function of this circuit is derived as follows:

$$G(j\omega) = \frac{E_2}{E_1} = \frac{\omega_b}{\omega_c} \times \frac{1 + j\left(\frac{\omega}{\omega_b}\right)}{1 + j\left(\frac{\omega}{\omega_c}\right)}$$

where $\omega_b = \dfrac{1}{R_1 C}$

$$\omega_c = \left(\frac{R_1 + R_2}{R_2}\right)\omega_b$$

Then,

$$\text{Log } G = \text{Log } \frac{\omega_b}{\omega_c} + \text{Log } \sqrt{1 + \left(\frac{\omega}{\omega_b}\right)^2} - \text{Log } \sqrt{1 + \left(\frac{\omega}{\omega_c}\right)^2}$$

From this relationship, the curve of Fig. 5b can be plotted. The stability of this network is apparent from the curve, whose peak is well below 90 deg. This is known as a phase lead network, since the phase of the transfer function is always positive.

This network is for insertion in a servomechanism system that is unstable because of excessive lag of the output quantity in respect to the input quantity. When this is done, the overall lag is reduced by virtue of the leading characteristic of the stabilizing circuit. The effect is much similar to that accomplished by adding capacitance to a power circuit to improve power factor.

In Fig. 6a, a phase lead network is

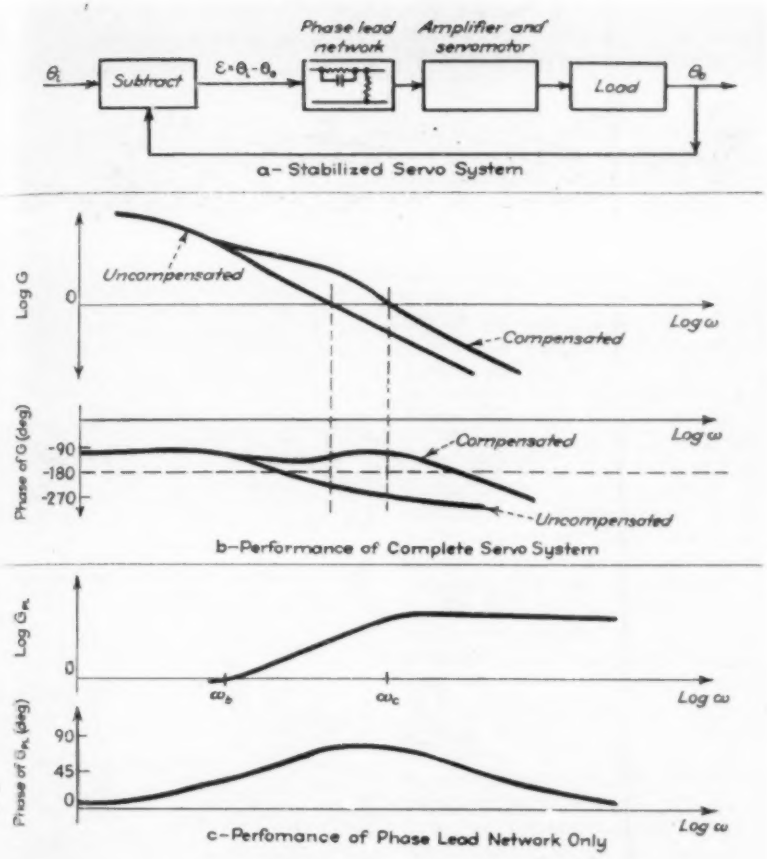


Fig. 6—Position of phase lead network in servo system is indicated in Sketch A. The performance curves in Part B, above, shows that the compensated system is now stable. Curves in Part C reflect the increase in amplifier gain needed when the phase lead circuit is installed in the system. Some power is lost in the components of this circuit.

Fig. 7—Block diagram of feedback control for a d-c generator. Such systems are commonly used to maintain terminal voltage constant despite changing loads. The controller must be absolutely stable in action.

shown as installed in a servomechanism. It is noted that the addition of the phase lead network reduces the phase lag of the complete system. The compensated curve in Fig. 6b is thus well above the abscissa of —180 deg, as required for stability. The servo loop was made stable by straddling the region of instability with ω_b and ω_c.

Referring to Fig. 5b, it is seen that the graph of log G vs log ω is below the zero axis. This is because there is a power loss in the phase lead network, so the gain of this network is a negative quantity. To offset this power loss or attenuation, the gain of the amplifier must be increased when a phase lead network is added. In Fig. 6c, the amplifier gain was increased by the factor of 1/log ω_b/ω_c to raise the gain curve for the phase lead network above the zero axis.

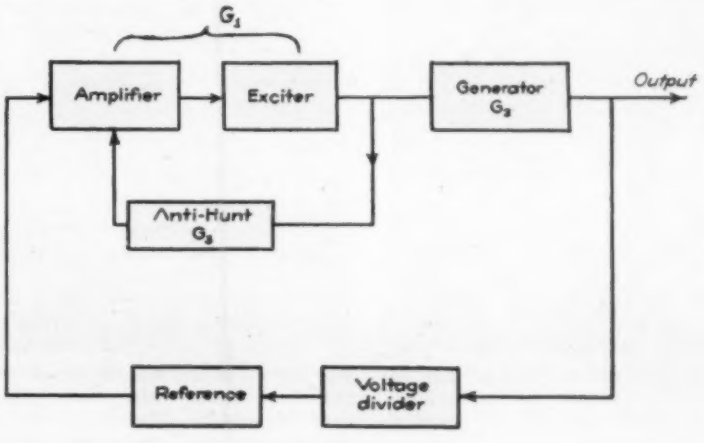
The third major stability arrangement consists of the insertion of an anti-hunt device in a feedback loop. Such devices actually detect a lagging condition that leads to unstability. When this condition is detected, a signal is transmitted to the input to reduce the phase angle of the error. The anti-hunt device may be a bridge circuit, a rotary limit switch, gyroscope or other.

This method requires a complex treatment inasmuch as the compensated transfer function cannot be readily obtained from the uncompensated one without a complete recalculation of the resulting transfer function product. Consequently, the effect of the anti-hunt network on the initial transfer function is not readily apparent. Feedback stabilization is in wide use, however, and is an excellent stabilizing means for servomechanisms and regulators of all types.

Another type of feedback stabilization involves the use of a tachometer generator that feeds back to the input a voltage proportional to the speed of the output. This increases the steady state velocity error. This error is in turn reduced to zero by adding to the input a sufficient amount of voltage from another tachometer generator which is proportional to the speed of the input.

Application

A description of a typical servomechanism helps to illustrate the logarithmic technique of testing stabilization. A voltage regulator is used in a feedback loop to maintain the output



voltage of a d-c generator constant. A block diagram of a particular 10 kw generator voltage regulator system is shown in Fig. 7. The exciter is a small d-c generator used to supply excitation current to the field coils of the main generator. Current for the field of the exciter is suplied by an electronic amplifier. The resulting generator armature voltage is fed back and "bucked" against a reference voltage such that the difference voltage is fed to the amplifier input. The system is stabilized by an anti-hunt feedback loop, within the main loop, feeding back part of the exciter armature voltage into the amplifier through a resistance-capacitance circuit.

The need for feedback stabilization can be explained qualitatively. Because of the inductance in the field circuits of the exciter generator and main generator, there is a cumulative time delay which is sufficient to make the regulator unstable when no anti-hunt stabilization is used. For example, if the output voltage of the main generator were too low, the regulator would act to increase the exciter field current. However, since the effect of the increased exciter field current is not felt immediately at the output, the regulator continues to increase the field current and ultimately the output becomes too high. Then the reverse action takes place. As a result, the output voltage oscillates or hunts about the desired value. To avoid this condition, an anti-hunt circuit is introduced. This feeds a portion of the exciter voltage back into the grid circuit of the amplifier. If, therefore, the exciter voltage is constant, the feedback has no effect. However, should the exciter voltage change, a voltage is introduced into the grid circuit of the amplifier. Since the exciter voltage must change before the main generator voltage can change, the feedback voltage in effect anticipates changes in the output voltage and so serves to stabilize the system.

The procedure for stabilizing the servomechanisms shown in Fig. 7 can be analyzed in detail. A plot of the experimental data obtained for the overall open system, (G_1G_2), of the actual regulator in Fig. 7 is shown in Fig 8. In obtaining these curves, the anti-hunt device was not included in the circuit. It is noted that log (G_1G_2) is greater than zero when the phase of (G_1G_2) is -180 deg. This means that the phase of (G_1G_2) will be more negative than -180 deg, when log (G_1G_2) is zero. Consequently the servomechanism is unstable when the loop is closed. In order to choose the proper network for G_3 to stabilize the voltage regulator, is is necessary to obtain the transfer function, G_1, of the amplifier and exciter alone. This transfer function can be calculated or measured directly. From the data obtained, the curves of Fig. 9 are plotted.

The anti-hunt circuit applied to stabilize the voltage regulator is shown in Fig. 10. The design of this circuit is based wholly on experience, so it is necessary to try the circuit in the regulator system to determine whether or not is will stabilize the system satisfactorily.

At the particular frequency corresponding to $\log_{10}\omega = 0.2$, the following data can be listed:

$$\left.\begin{aligned}\log (G_1G_2) &= 2.61 \angle -28 \text{ deg, from Fig. 8}\\ \log G_1 &= 2.83 \angle -12 \text{ deg, from Fig. 9}\end{aligned}\right]$$

Hence, by logarithmic subtraction,

$$\log G_2 = 0.22 \angle -16 \text{ deg}$$

By taking anti-logarithms, the following data is obtained:

$$\begin{aligned}\omega &= 1.58 \text{ radians/sec}\\ G_1 &= 675 \angle -12 \text{ deg}\\ G_2 &= 0.604 \angle -16 \text{ deg}\end{aligned}$$

The transfer function for the anti-hunt network sketched in Fig. 10 is as follows:

$$G_3 = \frac{E_2}{E_1}$$

$$= 1/4\left[\frac{25{,}000}{25{,}000 - \dfrac{j}{\omega \times 4 \times 10^{-6}}}\right]$$

$$= \frac{1}{4 - j\dfrac{40}{\omega}}$$

From this expression, it can be seen that for $\omega = 1.58$,

$$G_3 = 0.039 \angle 81 \text{ deg}$$

The equivalent transfer function for G_1 and G_3 is:

$$G_{eq} = \frac{G_1}{1 + G_1G_3} = 25.2 \angle -79 \text{ deg}$$

The total transfer function for the system is given as

$$\begin{aligned}G_T &= G_{eq} \times G_2\\ &= (25.2 \angle -79 \text{ deg})\,(0.604 \angle -16 \text{ deg})\\ &= 15.2 \angle -95 \text{ deg}\end{aligned}$$

Then, log $G_T = 1.182$

By repeating the above procedure at several other frequencies, sufficient points will be obtained to enable the calculated curve of Fig. 10 to be plotted. This curve shows that the phase of the overall transfer function is less than -180 deg when log G_T equals zero. Consequently, the regulator should be stable when the loop is closed.

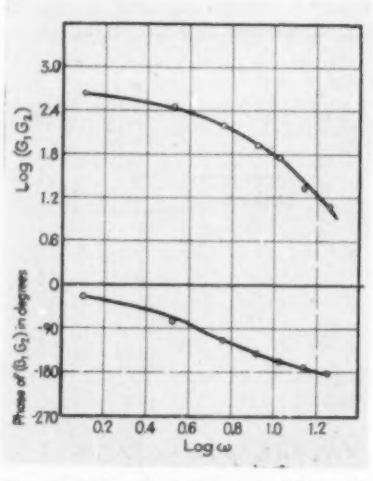


Fig. 8—Plot of experimental data obtained for the voltage regulator in Fig. 7 before anti-hunt network was installed. System is unstable.

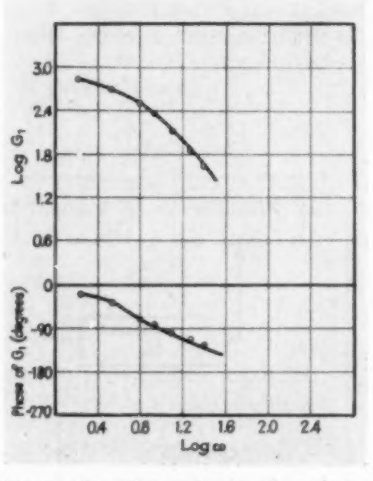


Fig. 9—Plot of transfer function of amplifier and exciter only. These curves must be used in determining type of anti-hunt network needed.

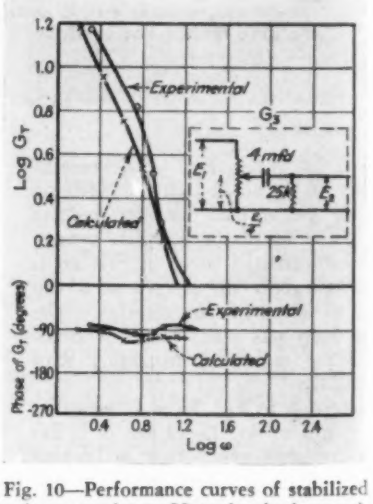
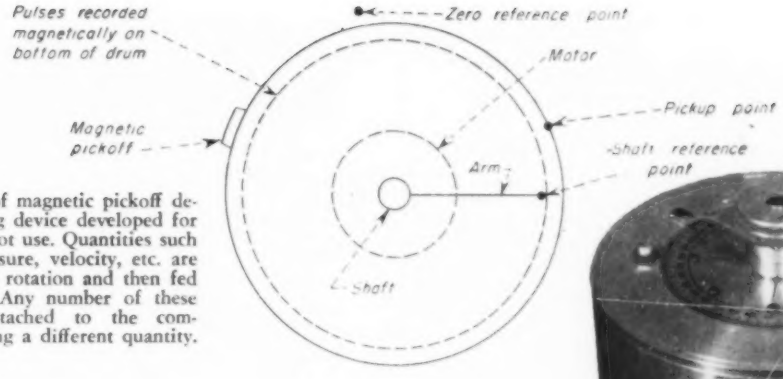


Fig. 10—Performance curves of stabilized voltage regulator. Note that both experimental and calculated values are closely similar. Inset shows the circuit used.



Schematic diagram of magnetic pickoff device. (Right) Sensing device developed for digital computer robot use. Quantities such as temperature, pressure, velocity, etc. are converted to a shaft rotation and then fed into the computer. Any number of these devices can be attached to the computer; each measuring a different quantity.

Sensing Device Turns Computer Into Robot

THE ABILITY OF ELECTRONIC digital computers to make rapid calculations involving many factors makes them potentially useful as robots to control the operation of complex equipment. But there has been one major obstacle. To operate as a robot, the computer must have a means to convert readings of temperature, pressure, position, velocity, etc. into a code that can be continuously fed into the computer.

A few physical quantities such as length and angle of rotation can be measured directly. A factor like temperature must be converted into a measurable physical quantity such as the rotation of a bimetallic element or the expansion of a mercury column. This basic conversion is called a transformation. If a transformed quantity is then changed to another physical quantity, the operation, called transducing, introduces an error. An example of this is measuring temperature as a rotation of a bimetallic element; the element turns a potentiometer shaft to produce an output voltage that is a function of temperature. This last operation introduces an avoidable error.

A basic principle in providing proper computer inputs is to avoid transducing operations.

In addition, when such a quantity is transformed to a measurable quantity, it must be measured with a known accuracy. The error introduced by the measurement can then be predicted and its effect taken into account in the determination of overall system accuracy.

One method of doing this is to transform the quantity into a shaft rotation. The rotation is measured by counting the number of small unit angles that make up the unknown angle. Such a measurement can be made with an accuracy of $\pm$ one unit angle. And size of the unit angle is selected to meet any accuracy requirements.

Key to the problem of making a robot is the development of a method of putting this shaft rotation into the computer without using a transducer operation. The Jacobs Instrument Company found a solution in magnetic and optical pickoff input devices made for use with the JAINCOMP (PRODUCT ENGINEERING, December 1951).

The accompanying schematic diagram shows a magnetic version of the device. An arm has been fastened to the shaft whose angle of rotation is to be determined. On the end of this arm is located a metal bar called the shaft reference point. A rotating disc, driven by a motor, is mounted below the shaft and coaxial with it. Fastened to this disc is a vertical pickup point.

The capacitance between the pickup point and the shaft reference point increases as the distance between the two decreases. The resulting current wave form is passed through a differentiating circuit to find the instant when the distance between these points is minimum. A similar circuit determines the instant when the distance between the zero reference point and the pickoff point is a minimum.

On the bottom of the rotating disc are recorded a series of equally spaced magnetic pulses. A magnetic pickoff detects these pulses as the disc rotates. The angle between two recorded pulses is a unit angle. Each time a unit angle is passed a pulse appears on the output of the magnetic pickoff. Then it passes through a gate to a counter.

When the vertical pickup point passes the zero reference point, the gate conducts pulses into the counter. When the vertical pickup point passes the shaft reference point, the gate is closed and no more pulses are counted. The number of pulses counted in this interval is equal to the measured angle of rotation in terms of unit angles. These can be transferred into the computer in a series or parallel fashion.

In a variation of the device, the rotating disc is made of glass and pulses are placed on it optically. This permits fine angular resolution since optical pulses can be applied with a density of 2,000 per inch as compared to 300 magnetic pulses per inch.

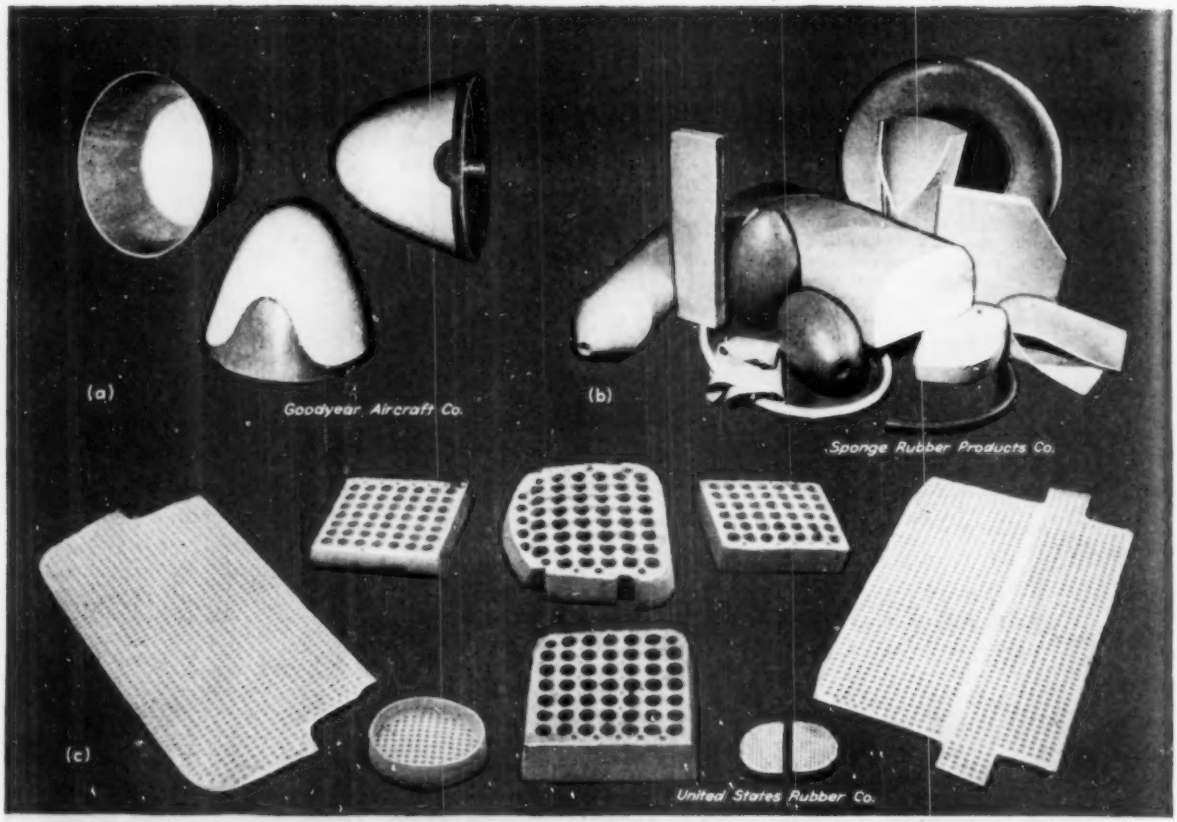


Fig. 1—(a) Aircraft radomes fabricated from a sandwich material with glass fabric reinforced polyester facings and foamed alkyd-isocyanate core. (b) Foamed vinyl flotation equipment includes life rings, fish floats and life preserver filling. The large log section is used in the construction of a 25 man Navy life raft. (c) Some expanded soft rubber cushioning products.

Foam Plastics *as Engineering*

Foam plastics are recently developed materials that offer many advantages to the engineer and designer because of their light weight and unique cellular structure.

FOAMED PLASTICS have gained prominence in recent years because of the increasing need for lighter weight structural materials. The foaming process has been applied to many plastic and rubber compositions. The major fields of application of these low density materials are:

(1) Light weight structural materials—primarily for aircraft applications at present.

(2) Thermal insulation.

(3) Shock absorption, cushioning and gasketing.

(4) Electrical and electronic uses.

The foamed materials in use today or in an advanced stage of development include the vinyls, phenolics, phenolic-rubber blends, polystyrene, styrene-butadiene blends, cellulose acetate, alkyd-isocyanate, hard and soft rubber compounds.

Foaming processes vary according to the material being foamed and the type of structure desired. Basically there are four methods of producing a foamed plastic:

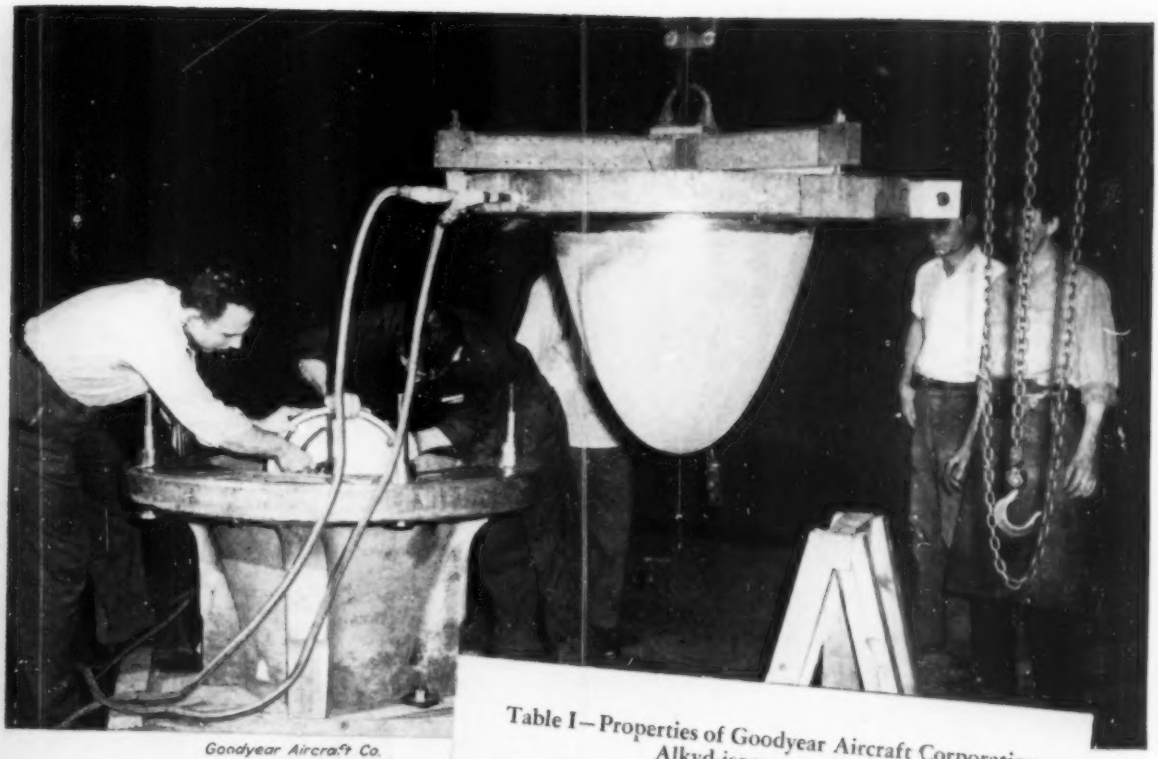
(1) Incorporation of air into a paste or latex by mechanical whipping.

(2) Introduction of nitrogen under pressure into soft or uncured stock.

(3) Inclusion of a foaming agent or gas-producing chemical into the mixture or compound.

(4) Chemical reaction of mixed resins to produce the final resin plus a gas.

The composition and density of foamed plastics can be controlled within limits to give the desired hardness, chemical resistance and strength and weight properties. The cellular structure can be made interconnecting or non-interconnecting through choice of



Goodyear Aircraft Co.

Fig. 2—Alkyd-isocyanate mixture being poured into the female mold prior to foaming-in-place of an aircraft radome. The heavy mold is required to withstand the pressure of the generated carbon dioxide.

Table I—Properties of Goodyear Aircraft Corporation Alkyd-isocyanate Foam

1. Density of core	10 lb./cu. ft.
2. Flatwise Tensile Strength (R26603)	200 psi at 77F
3. Flatwise Compressive Strength (R26603)	300-400 psi at 77F
4. Heat Distortion Temperature of Core	275F
5. Shear Strength (FPL 1561)	175 psi at 77F
6. The above properties decline from	12% to 19% at 170F
7. The adhesion of core to skin is at least	equal to the strength of the core itself.
8. Dielectric Constant of core at X-Band	1.20
9. Loss Tangent at X-Band	0.003
10. Thermal Conductivity	0.4
11. Impact (Falling Ball)	1 ft.-lb.
As Sandwich Using 0.30" Skins (116.14)	
12. Flexural Strength (R-12046-A)	80 lb./in. width
13. Edgewise Compression (R-12046-A)	1500 lb./in. width
14. Shear Modulus (FPL 1561)	9000 psi

Materials

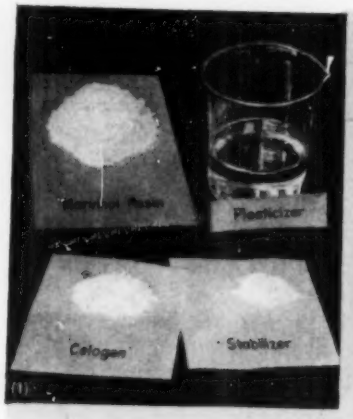
processing techniques. The incorporation of air by whipping invariably produces an interconnecting cell structure. The other three methods mentioned above produce either interconnecting or non-interconnecting cells.

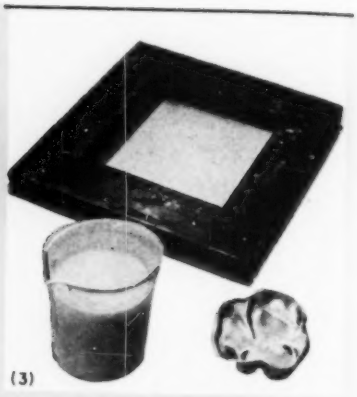
Each of the above processes is followed by a curing cycle. In the first case no externally applied pressure is necessary; in the second case pressure may or may not be used; in the third and fourth cases the mold must be kept under pressure to keep in the generated gases.

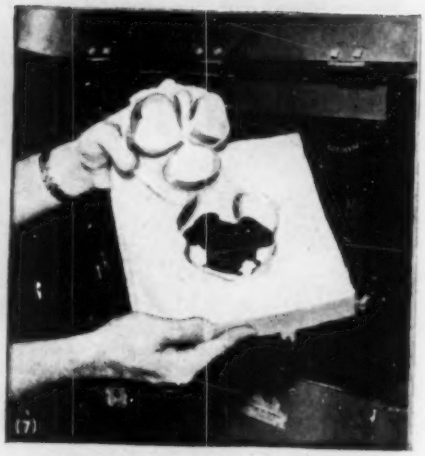
Low Density Structural Materials

Structural applications of foamed plastics have received considerable impetus from the recent aircraft construction defense program. Extensive research has been conducted by the U. S. Air Force in conjunction with various plastics manufacturers and aircraft industries. The major uses for these materials have been in sandwich construction for aircraft and for stabilizing hollow steel propellor blades and alloy control surfaces.

SANDWICH CONSTRUCTION. In aircraft applications sandwich constructions are particularly useful because of the possibility of using light-weight core materials to obtain strong rigid panels of minimum weight. The sandwich is made of three or more laminations of dissimilar materials that can be considered to be homogeneous when bonded together. The central layer, or core, serves to separate and to support the facings to give the panel sufficient thickness and stiffness to







A process for producing foam vinyl shapes using inexpensive molds was developed at the Naugatuck Division of the United States Rubber Company. Steps in the process are: (1) A vinyl plastisol is prepared consisting of vinyl resin, Tricresyl phosphate plasticizer, sulfonyl hydrazide (Celogen) blowing agent and one of a variety of stabilizers. (2) After mixing, a uniform dispersion is attained on a three roll mill.

Table II — Properties of Styrofoam (Expanded Polystyrene)

1. MECHANICAL PROPERTIES	For density of 1.3 lb/cu ft	For density of 1.6 lb/cu ft	For density of 2.0 cu ft
Compressive Yield Strength, psi	10-20	15-25	15-35
Tensile Strength, psi	30-40	50-70	80-100
Shear Strength, psi	15-25	25-35	35-45
Compressive Modulus, psi	450-1100	750-1350	1150-1750
Bending Modulus, psi	200-750	650-1200	1200-1900
Impact Strength, in.-lb.	0.5-1.2	1.1-1.8	2.1-2.7

2. THERMAL PROPERTIES

Thermal conductivity, BTU/sg.ft/hr/deg F/in.....0.23-0.30 at 40F
Linear Coeff. of Thermal Expansion, in/in/deg F.....2 to 5×10^{-5} between 32F and 50F
Specific Heat, BTU/lb/deg F.....0.27 at 40F
Resistance to Heat.....Max. recommended temp. for continuous use — 175F

3. ELECTRICAL PROPERTIES

Dielectric Constant.....less than 1.05 from 10^2 to 10^8 c.p.s.
Power Factor.....less than 0.0002 from 10^3 to 10^8 c.p.s.
Water Vapor Transmission.....1.5 to 3.0 grains/sq. ft./hr/in. of thickness/in. of Hg vapor pressure difference.

Table III — Thermal Insulation Properties of Expanded Plastics

Material	Trade Name	Density Range lb per cu. ft.	Thermal Conductivity (K Factor) BTU/sq.ft./hr/deg F/in
1. Expanded Polystyrene	Styrofoam	1.5-2.0	0.23-0.30
2. Aerated Urea Formaldehyde	Flotofoam	0.5-1.5	0.224
3. Phenolic Foam	G.-E.	3.0-5.0	0.24
4. Phenolic Foam	Insulfoam "B"	0.8-1.4	0.21-0.25
5. Cellular Cellulose Acetate	Strux	4.0-8.0	0.30-0.32
6. Cellular Rubber	Cell-Tite (soft)	8.0-18.0	0.27-0.30
7. Cellular Rubber	Cell-Tite (hard)	5.0-20.0	0.20-0.25

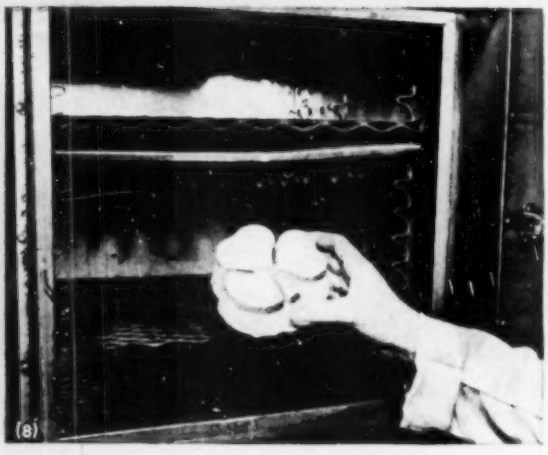
Dow Chemical Co.

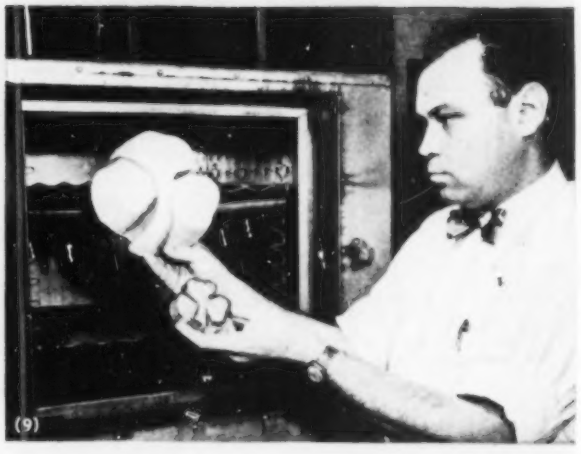
avoid elastic instability.

The expanded plastic materials are being used extensively as core materials because of processing and fabrication advantages, good density control and satisfactory strength, water resistance and electrical properties.

RADOMES. Foamed-in-place core materials are used in the construction of aircraft radomes, Fig 1a. The latter are the housings used for the protection of radar and gun fire control apparatus. The radome structure must be strong, light, easy to fabricate and have a satisfactory dielectric constant and low rate of water absorption. Formulations based on combinations of alkyd resins and metatolylene diisocyanate have proven satisfactory for this application. The foamed plastic is produced by the chemical reaction between these two resins with the accompanying liberation of carbon dioxide. Using this material densities can be varied between 3 and 30 pounds per cubic foot. The most commonly used material has a density of about 10 pounds per cubic foot.

The shape and wall thickness of radomes are quite critical. Their location on the aircraft necessitates streamlining to reduce air resistance. The wall thickness must be held to close tolerances to prevent interference to the radar waves. The thickness actually should be a multiple of the radar wave length. Some radomes require a varying section thickness to obtained





(3) The mold cavity is formed from a light gage aluminum sheet. In the case illustrated a cookie tin was used. This mold is placed in a heavy steel frame, capable of withstanding the high pressure developed during molding.

(4) The plastisol is poured into and around the aluminum mold, thus insuring equality of pressure on the mold walls during cure.

(5) The enclosed mold is placed in a heated hydraulic press. The heat produces decomposition of the blowing agent and the liberated nitrogen forms a uniform, fine unicellular structure.

(6) After completion of the press cure the mold is allowed to cool before it is opened. A limited amount of blowing occurs.

(7) The molded article is easily removed from the cavity.

(8) Completion of expansion is attained by heating the molded article in an oven at 200F or in boiling water.

(9) The final product has expanded 8 to 9 times the original volume of the mold. Expansion is uniform in all directions and accurate detail is retained.

Naugatuck Div., U. S. Rubber Co.

the desired reception. These requirements of section uniformity and odd shape are better fulfilled by the foamed-in-place sandwich construction than by previously used honeycomb constructions.

Advantages of the foamed-in-place isocyanate and glass reinforced polyester sandwich for radomes are:

(1) The radome shapes can be molded without resorting to laborious hand fitting. The previously molded facings are placed in the mold and liquid isocyanate poured into the cavity between them. The foam plastic produced during the curing cycle bonds readily to the surfaces of the polyester facings.

(2) Void-free glass cloth polyester facings such as those developed by Goodyear Aircraft Co. (Fig 3) can be used. The material allows for ready visual inspection for defects before assembly and offers greater resistance to delamination in rainy weather.

(3) Core joints are not necessary.

(4) No adhesives are needed. Sections of honeycomb structures occasionally fill with resin or adhesive, resulting in interference with electrical performance.

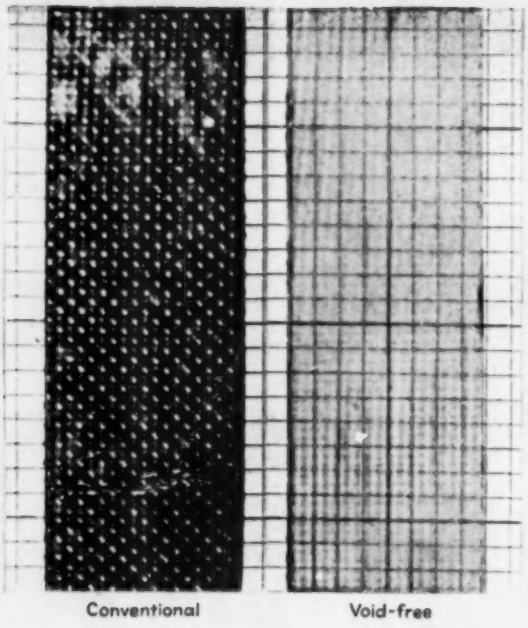
(5) Thickness can be held to close tolerances— ± 0.003 inches compared to approximately ± 0.015 inches using the honeycomb structure.

(6) Where a controlled varying thickness is required the foamed-in-place construction is almost mandatory.

(7) A uniform homogeneous structure is obtained.

The resins used for producing isocyanate foam are expensive and high cost matching metal dies are necessary for fabrication of curved structures. Some newer foams and processes show some improvement in cost and in curing time. The fabrication and functional advantages of the foamed-in-place construction, however, offset these material and mold costs.

PROPELLORS AND CONTROL SURFACES. The advantageous weight and material reduction obtained by the use of hollow propellors is accompanied by the disadvantage of surface skin flutter which can and does lead to



Goodyear Aircraft Co.

Fig. 3—Comparison of porosity and transparency of conventional and void-free glass fabric reinforced polyester radome facings. The void-free material allows for visual inspection of the core and is more resistant to delamination than the conventional material.

Goodyear Aircraft Co.

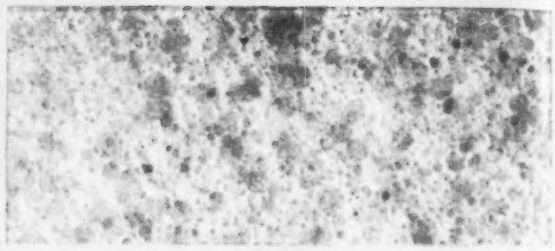


Fig. 4—Alkyd-isocyanate foam exhibits good uniform cellular structure when properly processed.

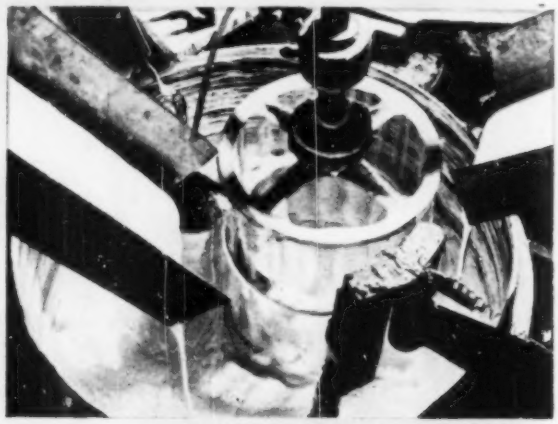


Fig. 6—(a) Air is whipped into rubber latex to produce an emulsion which cures to form light weight foam rubber.

fatigue failure. To offset this condition, the Hamilton Standards Division of the United Aircraft Co. developed a foamed-in-place material that can be injected into the hollow blade. The low density of this material (approximately 18 lb per cu. ft.) adds little in the way of weight to the propellor. The foam however has excellent adhesion to the steel surfaces and provides sufficient rigidity to prevent skin fluttering.

The foam is a mixture of nylon and phenol-formaldehyde blended with Hycar rubber. It is processed on standard rubber processing equipment prior to loading into the propellors. Although the material is strongly adhesive when cured against a clean metal surface, a combined adhesive and metal protective coating is used for double assurance of adhesion and protection against corrosion of areas not covered by the foam.

The nylon-phenolic-rubber composition has the following advantages over the hard rubber foam material formerly used:

(1) It is inert to the steel surface. The rubber compound produced corrosive attack.

(2) It is inert to many organic protective coatings in contrast to the hard rubber foam which either penetrated or produced solvent action on the coatings.

(3) It does not delaminate during processing.

(4) It has superior impact and fatigue strength.

(5) Processing is easier. No exothermic reaction is experienced.

Northrup Aircraft engineers have developed a successful method of using foamed polystyrene as an inner "filler" for control surfaces, (Fig 5), and by overall adhesion, are able to eliminate 80 percent of the rivets now used.

Part of the success of this application of foamed polystyrene is attributed to a recently developed adhesive for bonding the plastic to sheet metal. This adhesive is applied to all mating surfaces by spray or brush. A seal is effected by the vacuum bag method.

The use of foamed polystyrene as a substitute for ribs makes possible control surfaces as much as 15 percent larger in size, with decreases in weight up to 10 percent and increase in strength up to 10 percent. Vibration is practically eliminated by filling the voids within the control surface, making possible higher speeds.

Aluminum alloy control surfaces, such as aileron tabs, have been filled with foamed-in-place isocyanate and other plastics to provide added rigidity and to prevent skin fluttering. Some of these other materials include cellular cellulose acetate, foamed polystyrene and expanded rubber.

Ordnance Applications

The Naval Ordnance Laboratory has developed a foamed phenolic-rubber compound for possible use in closing plugs in semi-fixed ammunition cartridge cases. This type of ammunition is used in the Naval 5 in., 6 in. and 8 in. guns. The closing plug, which was of cork in older type guns, acts as a buffer between the cartridge case and the projectile during handling and ramming. The plug is expected to withstand this severe treatment and

Northrup Aircraft, Inc.

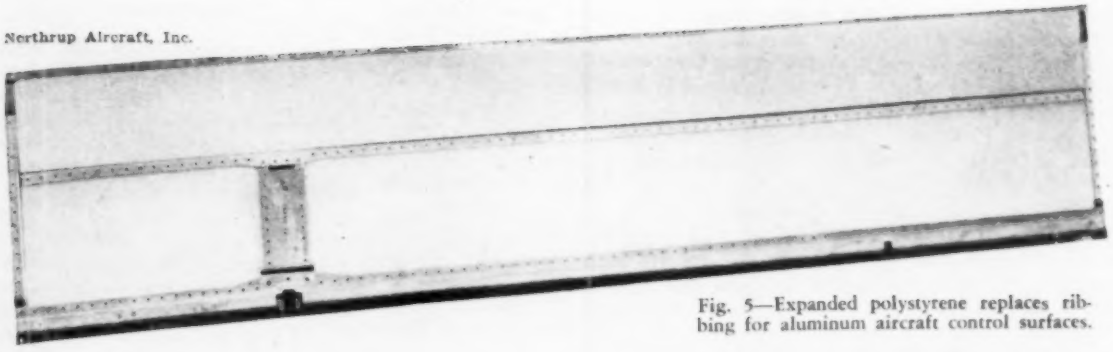
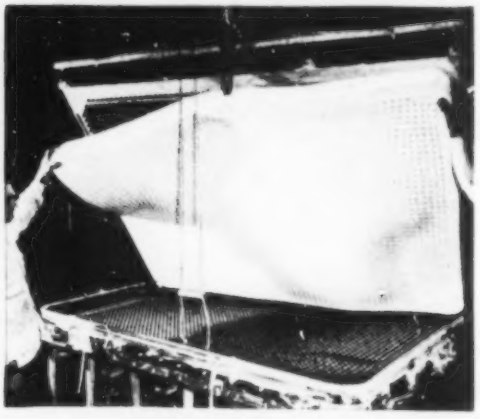


Fig. 5—Expanded polystyrene replaces ribbing for aluminum aircraft control surfaces.

United States Rubber Co.

(b) The whipped foam is shown being poured into the lower half of a large mattress mold. The workman is judging the amount of fill.



(c) The final molded foam rubber mattress is easily removed from the waffle-like mold.

yet break into small harmless particles during the firing of the gun. Cork has been found too weak to withstand the buffetting that occurs in the newer rapid fire guns and has the additional disadvantage of occasionally catching on fire and burning on the deck after being pulverized in the gun. The new foamed phenolic-rubber compound shows promise of correcting the difficulties encountered with cork.

Flotation Equipment

The light weight of the expanded plastics suggests their applicability to the production of flotation equipment. One of the early applications of Styrofoam was to provide buoyancy in life rafts and other marine emergency rescue equipment. Its closed cellular structure and extremely low water absorption and low density were specific advantages.

The foamed vinyls are coming into prominence in this field. Fish floats, life rings, Fig 1 (b), and a 25 man Navy life raft are some of the products successfully made from expanded vinyl. This material does not crush and has good strength to weight properties. Its resistance to burning is an additional advantage over other foamed materials.

Expanded Plastics for Thermal Insulation

The foamed plastic materials have good thermal insulation properties and offer advantages over other insulation materials. These include low moisture absorption, light weight combined with structural strength, ease of fabrication and installation. The plastics used in this field include foamed polystyrene, foamed-in-place phenolics, aerated urea formaldehyde, cellular cellulose acetate, cellular rubber, expanded vinyl.

Expanded polystyrene, marketed by the Dow Chemical Co. under the name of Styrofoam, has an average thermal conductivity or K factor of 0.27 BTU/sq ft/hr/deg F/ inch which compares favorably with the better commercially available non-foamed materials. Its greatest asset is its low moisture absorption, in the range of 2 to 6 percent by volume, even under extended immersion. The closed cell structure impedes the passage of water or vapor by capillary action.

Other outstanding properties of Styrofoam are its good compressive strength, permiting its use in the construction of self-supporting partitions, its freedom from odor, its durability, light weight and low cost.

Since polystyrene is a thermoplastic it is limited to use at temperatures below 175F. Its major application is as a low temperature insulation for freezers, refrigeration equipment and piping and for residential insulation.

Foamed urea-formaldehyde is an aerated thermoplastic containing 99.15 percent air by volume. It was developed by the U. S. Rubber Co. and designated as Flotofoam. It does not have a true closed cell structure and consequently is subject to water and moisture absorption by capillary action.

Flotofoam's advantageous features include low thermal conductivity, low density and self-extinguishing, non-corrosive and non-toxic properties.

The foamed-in-place phenolics are

also used for insulation purposes. The material is available in liquid form and foamed at the scene of the construction—with the advantage of saving costly shipping space. General Electric and Westinghouse have produced foamed phenolics. The G-E material is also available in foamed slabs.

The phenolic foams have an open cell structure similar to the aerated urea-formaldehyde and consequently do not have the moisture resistance of polystyrene. Operating temperatures are higher for the phenolic foam, however—up to 300 F for continuous service. The presence of formaldehyde odor renders this foam objectionable in household refrigeration applications.

Cellular cellulose acetate does not have as acceptable a K factor as other foamed plastics but it has good heat resistance (390F, max), good moisture absorption, and light weight combined with outstanding physical strength. Some of its strength properties include: compressive strength, 128 to 235 psi; tensile strength, 112 to 183 psi; flexural strength 73 to 177 psi, depending upon the density.

Cellular rubber is used in both the hard and resilient forms for thermal insulation. It is made by expanding either natural or synthetic rubber with nitrogen to produce a uniform non-interconnecting cell structure. The soft material varies in density from 8 to 18 lb per cu ft with a *K* factor of 0.27 to 0.30; the hard material ranges in density from 5 to 20 lb per cu ft and has a 0.20 to 0.25 *K* factor. The hard material, such as Sponge Rubber Products Company's Cell-Tite can be post-formed by heating and shaping.

The combination of light weight, good *K* factor, and good chemical resistance make cellular rubber suitable as a thermal insulating medium that is subject to contact oils, fats or solvents.

The foamed vinyls are the newer expanded plastics to enter the insulation field. They are characterized by their toughness, good insulation properties, non-inflammability and non-corrosiveness.

Shock Absorption Applications

The softer, more resilient foamed materials, Fig. 6, find extensive application as shock absorbing media. This field includes protective packaging, padding, engine or equipment mounts for reduction of undesirable shock or vibration, and comfort rendering equipment such as seat cushions, arm rests, rug underlay and mattresses.

Foamed soft rubber is the most widely used material for the above applications. Expanded vinyl is finding some use for crash protective padding inside tanks or planes because of its "deadness" or lesser rebound tendency.

Foamed rubber and vinyl are useful as gasketing and sealing materials, especially in refrigeration equipment and other low temperature applications where their insulative properties can be used to advantage.

Embedments for Electrical Components

Foamed-in-place resins are being used as embedment materials for electrical and electronic components. The components or groups of components are completely embedded in the resin as a protection against shock, moisture, dirt and fungus. The foamed materials offer the advantages of light weight, low dielectric constant and power factor, low moisture absorption and good resistance to shock and deterioration. They have the disadvantages of poor heat dissipation and poor resistance to distortion by heat. Diisocyanate type foams, such as Lockheed Aircraft Corporation's "Lockfoam" and Melpar, Inc. foam resin have been used successfully.

The extent of the foam plastic development now in progress in the above fields presages a large increase in their applications. Present use has been deterred by high price and poor availability. The foamed-in-place resins can be expected to find application in light weight panel construction, such as refrigerator doors and cabinets, table tops, housings for electrical and mechanical equipment. In France an entire radio station was lined with foam plastic panels for insulative and acoustical purposes. The role of foam plastics in reducing the effects of noise and vibration will also expand.

The potentiality of these materials is sufficient to warrant their consideration in present and future structural and functional design.

Big Future Predicted for Aerosol Paint Units

WASHINGTON—Paint makers have hardly scratched the surface of the aerosol paint spray market, according to Paul Engstrum who runs an aerosol research laboratory in Washington. Engstrum has recently developed a non-clogging valve for the spray bomb.

Since the introduction of aerosol propelled insecticides to the consumer market in 1946, paint manufacturers have been eyeing the obvious marketing advantages of a self-contained aerosol bomb.

Most paint manufacturers deferred the step into the aerosol field for three reasons: some doubt of consumer acceptance; a lack of technical information on the proper methods of mixing paint and liquified propellant; and lack of an adequate paint valve. Success of the insecticide industry in the use of aerosols has effectively answered the first reason. More paint aerosols are not sold because of trouble with valves. The valve problem and insufficient knowledge about formulations have prevented paint makers from getting enough paint into the aerosol bombs.

In a 12-ounce container, the paint maker should get 70 percent paint and 30 percent gas, Engstrum said. Studies of one sample have shown that the 12-ounce bomb contained but 8.8 percent solids, while the paint should be about 30 percent solids.

Engstrum has designed a needle valve in which a needle or pin made of special material is placed at the outlet. Each time the valve is opened or closed, the needle action wipes the residue from the orifice. He claims his valve will permit formulations containing up to 30 percent solids.

Engstrum sees many possibilities for the aerosol spray bomb. One of these is a small "touch-up" paint bomb to be put on every car as it leaves the auto factory. The bomb would contain the color of the paint used on that car and the owner would use it to spray over scratches. It could also be used by repair shops for minor repainting jobs on the car after a fender or body job.

Engstrum's research laboratory is now working on a contract with the Army Ordnance Department for development of an aerosol formulation for an ignition insulating compound. This compound is to be used on engines for protecting the ignition system from shorting caused by moisture. These compounds are now brushed on with long camel-hair brushes; brushing does not reach the difficult spots and is time-consuming.

Paint firms themselves are at work too. The National Paint, Varnish and Lacquer Association states that every major paint maker is working on aerosols. Several are supporting studies at an industrial research laboratory.

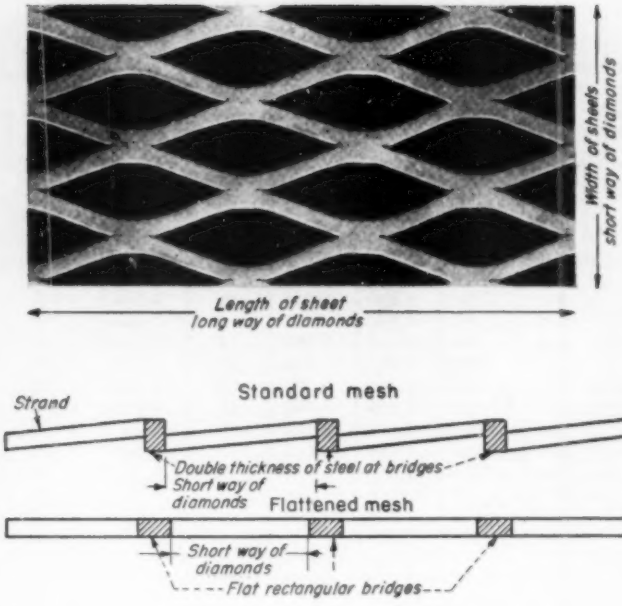


Fig. 1—Long dimension of diamonds and sheet are parallel in both standard and flattened mesh. Sectional views show relative positions of bridges.

Expanded Metal

A sheet of carbon steel, stainless, aluminum, or special-property alloy goes a long way when made into a diamond-shaped lattice having high strength and rigidity. A few of the many applications are machine guards, ventilating panels, functional and decorative parts in electrical assemblies.

ROBERT P. INGOLS
Penn Metal Company, Inc.

WHEN A SHEET OF STEEL, aluminum or Inconel is cut and spread to form a sheet of expanded metal, up to a ten-fold increase in sheet area takes place. The resulting lattice structure has high strength and rigidity, and can be formed, fastened, welded and finished according to standard procedures. The principal uses for this material are therefore in assemblies where the passage of air through the sheet is important, where weight must be relatively low or where a protective barrier around a moving part is needed.

Expanded metal is made in two types—standard and flattened. The solid stock is cut and drawn into open mesh sheets eight feet long in various widths and gages by a die-knife so that even diamonds are formed with uniform strands. Each row is joined by successive uncut portions or bridges of metal. The process is similar to cold drawing and increases the strength of the steel in the finished sheets through cold working. All burrs and sharp edges are removed to insure safe handling. Fig. 1 shows the "vertical" bridges and slanting strands of the standard sheet. Rigidity is the result of the increase in thickness at the intersection of the diamonds. This makes the material particularly adaptable to large vertical machine guards because sag in the finished panel is less than would occur when perforated sheet or woven wire is used.

Flattened expanded metal is made by the same basic process as the standard type, except that after the expanding operation, the sheet is then passed through flattening rolls when

Table I—Sheet Data for Standard Mesh Carbon Steel Expanded Metal*

Nominal size of mesh, in.	Weight, lb/sq ft		Dimensions of sheet, ft	Normal size of mesh, center-to-center of bridges, in.		Size of strands, in.		U. S. Std Gage	Size of opening, in.	
	Plain	Galv		Width	Length	Thick	Width		Width	Length
1/4—No. 20	0.86	1.29	4 x 8	0.2500	1.000	0.036	0.073	20	0.172	0.718
No. 18	1.14	1.71	4 x 8	0.2500	1.000	0.048	0.073	18	0.172	0.718
1/2—No. 40	0.40	0.50	4 & 6 x 8	0.4620	1.200	0.048	0.047	18	0.437	0.937
No. 18	0.74	0.91	4 & 6 x 8	0.4620	1.200	0.048	0.086	18	0.375	0.937
No. 16	0.84	0.97	4 & 6 x 8	0.4620	1.200	0.060	0.078	16	0.375	0.937
No. 13	1.47	1.73	4 & 6 x 8	0.4620	1.200	0.090	0.091	13	0.344	0.906
3/4—No. 16	0.50	0.59	4 & 6 x 8	0.9230	2.000	0.060	0.092	16	0.812	1.750
No. 13	0.80	0.92	4 & 6 x 8	0.9230	2.000	0.090	0.098	13	0.750	1.688
No. 10	1.20	1.36	4 & 6 x 8	0.9230	2.000	0.090	0.148	13	0.750	1.625
No. 9	1.80	1.95	4 & 6 x 8	0.9230	2.000	0.134	0.148	10	0.688	1.562
1 —No. 16	0.44	0.51	4 x 8	1.0000	2.400	0.060	0.089	16	0.875	1.937
1 1/2—No. 18	0.20	0.28	4 x 8	1.3300	3.000	0.048	0.068	18	1.312	2.625
No. 16	0.40	0.48	4 x 8	1.3300	3.000	0.060	0.107	16	1.250	2.625
No. 13	0.60	0.68	4 & 6 x 8	1.3300	3.000	0.090	0.107	13	1.187	2.500
No. 10	0.79	0.89	4 & 6 x 8	1.3300	3.000	0.090	0.140	13	1.187	2.500
No. 9	1.20	1.31	4 & 6 x 8	1.3300	3.000	0.134	0.143	10	1.125	2.375

* Similar data are available for the flattened mesh material. Values for weight/square foot, thickness of strands and size of openings are slightly less than for the standard mesh; normal center-to-center length of mesh and width of strands are slightly more. Sheet widths are either 4 by 8 or 3 & 4 by 8 feet.

Table II—Sheet Data for Stainless Steel (Type 302) Expanded Metal

Nominal size of mesh, in.	Wt, lb/ sq ft	Dimensions of sheet, ft	Normal size of mesh, center-to-center of bridges, in.		Size of strands, in.		U. S. Std Gage	Size of opening, in.	
			Width	Length	Thick	Width		Width	Length
STANDARD MESH									
1/2—No. 18	0.78	4 & 6 x 8	0.460	1.20	0.050	0.086	18	0.375	0.937
No. 16	0.98	4 & 6 x 8	0.460	1.20	0.063	0.086	16	0.375	0.937
3/4—No. 18	0.47	4 & 6 x 8	0.923	2.00	0.050	0.099	18	0.812	1.750
No. 16	0.59	4 & 6 x 8	0.923	2.00	0.063	0.104	16	0.812	1.750
1 1/2—No. 16	0.43	4 & 6 x 8	1.330	3.00	0.063	0.109	16	1.250	2.625
FLATTENED MESH									
1/2—No. 18	0.74	3 & 4 x 8	0.460	1.26	0.039	0.101	18	0.250	1.000
No. 16	0.93	3 & 4 x 8	0.460	1.26	0.051	0.101	16	0.250	1.000
3/4—No. 18	0.45	3 & 4 x 8	0.923	2.10	0.039	0.105	18	0.750	1.781
No. 16	0.56	3 & 4 x 8	0.923	2.10	0.051	0.105	16	0.750	1.781
1 1/2—No. 16	0.41	3 & 4 x 8	1.330	3.15	0.051	0.127	16	1.062	2.750

cold. This procedure, in addition to returning the physical properties obtained by cold-drawing, gives the sheet a flat appearance, Fig. 1, similar to perforated sheet with diamond-shaped openings. The sheet as finished is approximately two gages lighter than the original stock but is stronger than perforated sheet of like thickness.

Sheet dimensions are given as the width by the length. The mesh opening is defined by the nominal dimension, the short way of the diamond (SWD) from center to center of the bridges. A typical description is ½ in. #18 6-0 x 8-0 or a sheet 6 ft wide by 8 ft long with a mesh that is ½ in. across the short dimension of the diamond. The number "18" generally corresponds to the original gage of the metal before expansion. The actual gage used is also listed in Tables I and II to show where there is a difference.

Dimensions shown in the tables for center-to-center mesh size, size of strands and size of opening should be used wherever possible when selecting the mesh for a given design, because they apply to standard material. In cases where a design demands slight divergence from the values in the tables, special dimensions can be specified. Delays in procuring material and additional expense usually accompany such changes.

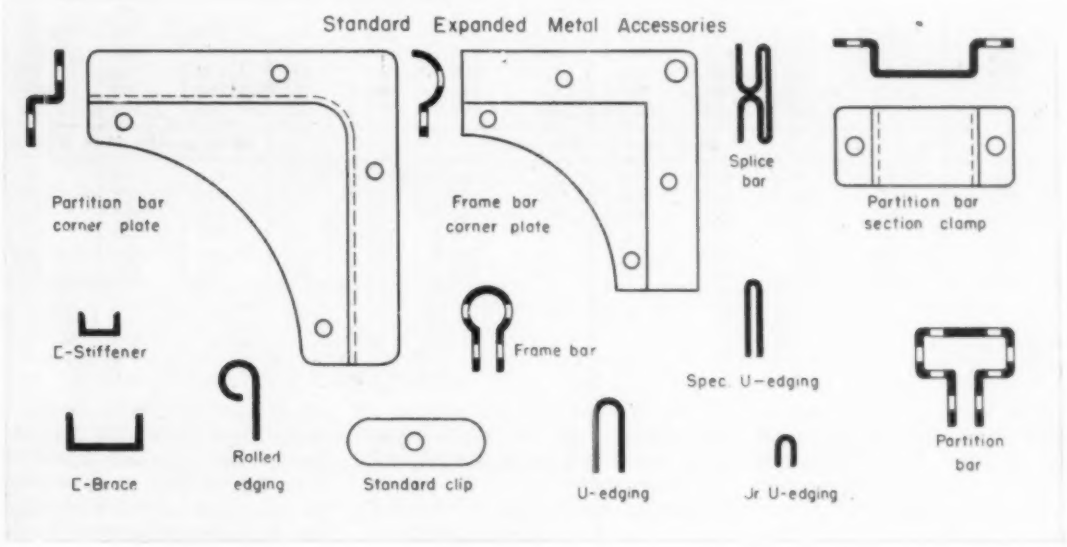
In designs involving the passage of air through expanded metal, the main consideration is the unobstructed flow, Table III, through a given area. Generally, the standard mesh is preferred to the flattened material because there

Table III—Air Flow Comparison

Nominal size of mesh, in.	Unobstructed air flow, cu ft/min for various velocities, ft/min		
	500	1,500	3,000
STANDARD MESH			
1/2—No. 18	410	1,275	2,430
3/4—No. 16	475	1,395	2,760
No. 13	450	1,365	2,670
No. 10	410	1,305	2,550
No. 9	405	1,230	2,430
1 1/2—No. 13	490	1,425	2,790
No. 10	470	1,365	2,640
No. 9	460	1,335	2,700
FLATTENED MESH			
1/2—No 18	360	1,140	2,250
No. 16	375	1,155	2,250
3/4—No. 16	400	1,260	2,430
No. 14	400	1,245	2,400
No. 9	390	1,200	2,310
1 1/2—No. 16	470	1,350	2,640
No. 14	480	1,365	2,700
No. 9	475	1,365	2,670

Table IV—Free Openings

Nominal size of mesh, in.	Percentage of openings (approx)	
	Min	Max
STANDARD MESH		
1/2—No. 18	66	71
3/4—No. 16	83	88
No. 13	74	79
No. 10	71	76
No. 9	61	66
1 1/2—No. 13	81	86
No. 10	79	84
No. 9	73	78
FLATTENED MESH		
1/2—No. 18	55	60
No. 16	50	55
3/4—No. 16	67	72
No. 14	63	68
No. 9	53	58
1 1/2—No. 16	80	85
No. 14	77	82
No. 9	73	78



is a larger percentage of open area, Table IV, resulting from the configuration of the bridges and strands, as shown in Fig. 1. Percentages of open area range from 61 to 88 for standard and 50 to 85 for flattened material.

There are many factors that influence the selection of the mesh for a design involving air flow. As these factors vary widely, it is best to consult the supplier before making a choice.

The question is frequently asked, "What weight mesh should be used to obtain a certain deflection under a given load?" This question cannot be answered without knowing the type of frame construction, if any, that is being used or the type of fastening that is contemplated if no framing is done. Table V lists loads and deflections for various sizes of mesh.

It is often more economical to use a light frame and heavy mesh than it is to use light mesh and heavy framing members. Generally, the framing or reinforcing members when applied and fabricated are more expensive than the heavy mesh. Naturally, if the mesh is applied to the frame in a permanent manner—welded or securely bolted—the load bearing capacity of the mesh is augmented by the capacity of the frame and vice versa.

In the selection and application of expanded metal, it should be noted that there is more resistance to bending along an axis running across the short dimension of the diamond than along the other axis. Therefore, in the design of a rectangular sheet, the long dimension of the diamond should span the short dimension of the sheet. In

Table V—Deflection for Various Loads

STANDARD MESH

Deflection, in.	Load in lb for various sizes of mesh, in.								Load in lb for various meshes, in.		
	12-in. span by 12 in. wide								12-in. span by 24 in. wide		
	1/2	3/4				1 1/2			3/4		1 1/2
	No. 18	No. 16	No. 13	No. 10	No. 9	No. 13	No. 10	No. 9	No. 13	No. 9	No. 9
1/8	70	65	55	135	155	45	90	100	110	290	190
1/4	140	130	155	275	340	100	170	210	315	600	570
3/8	225	190	240	410	485	140	230	360	450	1,110	960
1/2	320	255	300	560	675	220	315	525	560	1,860	1,405
5/8	475	305	405	750	895	270	390	700	775	3,320	1,940
3/4	640	350	540	950	1,150	320	480	875	1,030	4,020	2,580
	24-in. span by 12 in. wide								24-in. span by 24 in. wide		
1/8	35	25	35	40	55	20	25	30	60	90	55
1/4	70	50	60	80	110	40	50	55	100	190	100
3/8	95	65	85	100	180	55	70	85	135	390	150
1/2	120	85	110	120	260	75	90	105	170	610	290
5/8	165	95	135	150	365	100	115	120	275	980	450
3/4	210	110	160	190	500	120	150	150	375	1,180	675

FLATTENED MESH

Deflection, in.	12-in. span by 12 in. wide								12-in. span by 24 in. wide		
	1/2		3/4			1 1/2			3/4	1 1/2	
	No. 18	No. 16	No. 16	No. 14	No. 9	No. 16	No. 14	No. 9	No. 14	No. 14	No. 9
1/8	100	115	95	120	170	80	100	120	205	160	200
1/4	200	230	205	240	350	175	200	250	440	340	530
3/8	335	420	385	415	580	270	320	405	1,025	500	920
1/2	500	680	530	570	765	400	450	550	1,860	750	1,550
5/8	900	1,035	825	860	1,035	510	635	765	2,950	1,000	2,260
3/4	1,375	1,400	1,135	1,200	1,310	625	875	1,000	4,160	1,610	3,290
	24-in. span by 12 in. wide								24-in. span by 24 in. wide		
1/8	60	70	50	70	115	30	40	50	115	60	75
1/4	125	140	100	145	210	60	80	110	175	135	160
3/8	210	250	175	220	275	80	135	165	300	225	255
1/2	300	350	250	300	335	100	200	225	400	285	360
5/8	420	505	370	410	530	140	285	310	480	350	550
3/4	540	660	480	560	760	160	370	400	740	540	810

this manner the inherent strength of expanded metal reduces deflections.

Expanded metal, like ordinary steel sheet, is usually fabricated to some extent before it is applied. This may merely consist of shearing and painting or it may involve several other operations such as bending, framing, welding or reinforcing. It can be sheared crosswise of the diamond (in the short direction) along a line of bridges. However, it is difficult, if not impossible, to shear along the bridges the long way of the mesh.

It is generally more economical to apply edging to the raw sheared edges than it is to cut on the center line of bridges. Edging can be one of the standard rolled products shown above or of special design for a given application. In cases where framing of angles is used or where the expanded metal is applied on the inside of a sheet metal container or cabinet, no edging is required. The purpose of the edging is to provide a safe edge and is not economical unless absolutely necessary.

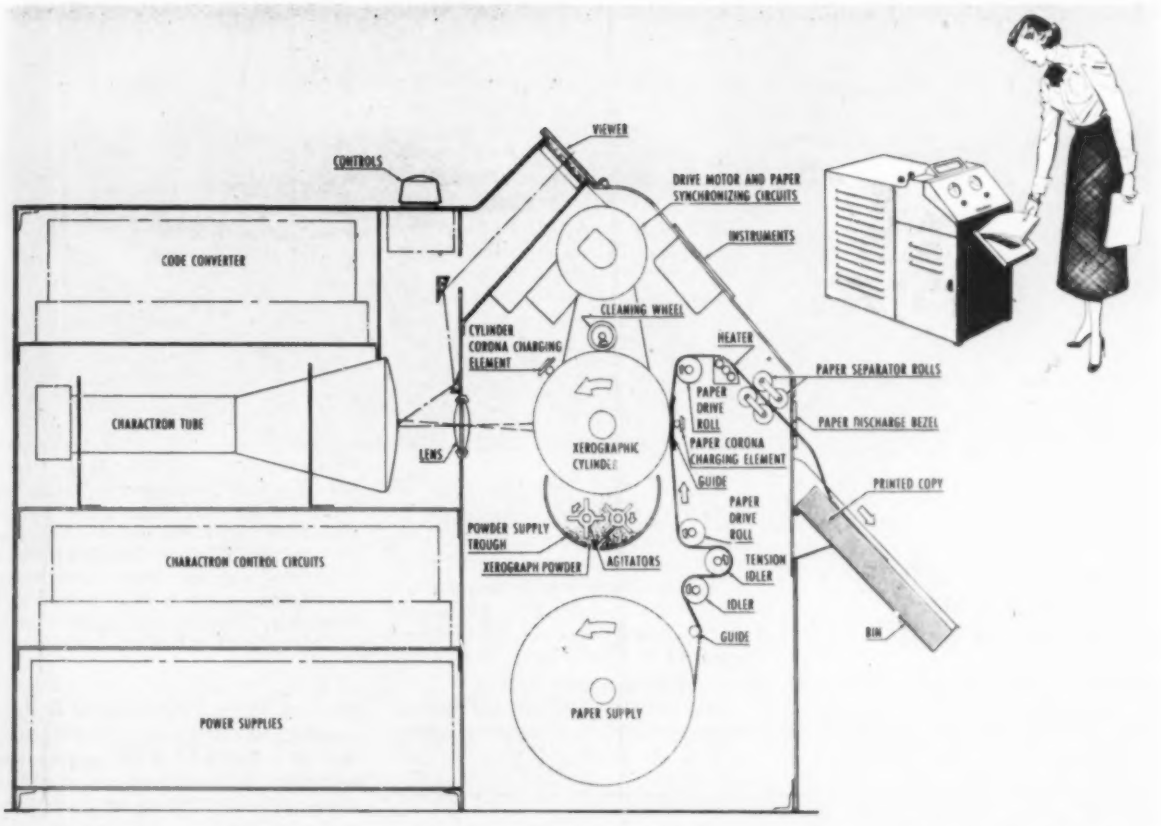
Expanded metal can be welded by any of the conventional methods, although special precautions should be taken with aluminum. Arc, spot or pressure welding is most commonly used. In arc welding, the size of the electrode should be in proportion to the size of the stands; usually $\frac{3}{32}$ to $\frac{5}{32}$ in. rod is best. Coated rod is considered best on all uses except where galvanizing is involved. A light welding machine is preferable to a heavy machine with reduced amperage.

Little warpage is encountered when arc welding is used because the nature of the mesh tends to localize the expansion that takes place at welding temperatures. Welding mesh into solid prefabricated frames requires intermittent welds (spacing and filling in) if buckling is to be avoided. One method is to make every third weld in the first operation and then fill in.

In gas welding, more warpage or buckling generally occurs because the heat is distributed over a larger area than in arc welding. The chief advantage of this technique is the smoother finish obtained. In either gas or arc welding, as well as in spot welding, it is desirable that the mesh and framing members be as nearly equal in gage as possible.

Although plain carbon steel expanded metal is generally used, stainless steel and aluminum are gaining in popularity. New uses in chemical handling, food handling, refrigeration, radio and television sets are being developed. Monel, Inconel and nickel expanded metal have recently been put on the market as standard items for use in applications where the special properties justify the cost.

TECHNICAL NEWS



CHARACTRON HIGH SPEED PRINTER is combined with Xerographic printing equipment to provide a small, versatile unit capable of reproducing electronic pulses into readable information on paper at speeds of 20 in. of paper per second without film or liquid chemical processes. The proposed unit is small enough to conveniently fit most offices.

Tube Changes Electronic Impulses Into Visual Information

AN ELECTRONIC TUBE developed by Consolidated Vultee Aircraft Corp. changes electronic impulses into visual information that can be viewed on a screen or reproduced for permanent record on ordinary paper. Called the Charactron, the tube can transform information at the rate of 10,000 characters per second.

The Charactron has a unique design among cathode ray tubes. A matrix containing character-shaped openings is located between an electron gun and the fluorescent screen at the viewing end of the tube. Electric-static fields selectively direct a stream of electrons through the matric openings and form a shaped beam. This beam produces characters on the screen of the tube where they can be read or recorded.

Either electro-static or electro-magnetic deflection places the character image on the viewing screen in the same manner as in a television tube. Proper sequence of applied deflection voltages selects and positions the matrix characters.

Convair has put the Charactron in a printer that uses the Haloid Company's Xerography reproduction process. This device called the Charactron High-Speed Printer operates at a printing speed of 20 in. of paper per second And the printing is done directly on newsprint or multilith paper, without using film or chemical processing.

Current development work includes application of the Charactron to the computor field and to special military projects.

One big use anticipated for the printer is the reproduction of information supplied by high-speed computers. By producing tabulations and data directly on paper as fast as the computer turns them out, the printer will reduce the time required to move this information from the computing section to the design section.

The device can also be used to make performance studies over periods of time ranging from a fraction of a second to many minutes. These studies might include vibration analysis, determination of servo-system parameters, wind-tunnel tests, and conversion of tele-metering data.

One important type of data converter being considered is equipment that will measure physical quantities in the form of electrical potentials and present them as three-place numerals on the viewing screen of the Charactron tube. In such equipment, the voltage levels can be converted to decimal number values within a few milliseconds and with an accuracy of one part in one thousand.

Deformation of Two-Phase Alloys Studied

MELBOURNE—Using wire drawing as the method, and crystallization temperature as an index of the degree of deformation, scientists of the Australian Commonwealth Scientific and Industrial Research Organization have made extensive studies on the deformation effects of two-phase alloys.

In duplex brass, it was found that crystals of both phases in alloys containing more than 30 percent by volume of the hard phase deformed to the same extent for a total deformation up to 80% reduction in area. In alloys containing 10 and 20 percent by volume of the hard phase, the heavier deformation always occured in the softer phase with the difference in deformation of the two phases becoming less as the total deformation increased beyond a 50 percent reduction in area.

Effects of Nitrogen on Low-Temperature Brittleness of Steel

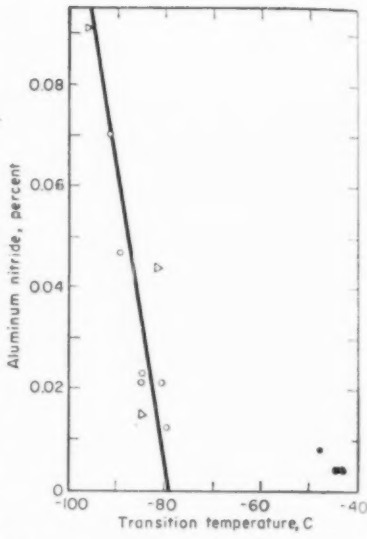
THE NATIONAL BUREAU OF STANDARDS, investigating low temperature properties of steels, has found that the effect of nitrogen content depends on the chemical form in which the nitrogen is found.

Nitrogen, if present as aluminum nitride, improves low temperature notch-toughness, and lowers the temperature at which the steel becomes brittle. But nitrogen in the form of nitrides of iron or manganese is detrimental; decreasing notch-toughness and raising the transition temperature. A certain amount of nitrogen finds its way into steel during manufacture even though it is not added on purpose.

Samples studied at NBS were 0.3 percent carbon steels containing 0.9 or 1.6 percent manganese, 0.2 to 0.3 per cent silicon, and variable quantities of nitrogen. V-notched specimens were fractured in Charpy impact tests at temperatures ranging from —320 to —212 F. These samples became brittle at temperatures from —50 to —60 F.

Additional steel samples were aluminum-treated. This changed the nitrogen into aluminum nitride. As the percentage of aluminum nitride increased, the transition temperature was lowered to —140 F. Aluminum-treated samples fractured at temperatures 54 to 90 degrees Fahrenheit lower than untreated steels.

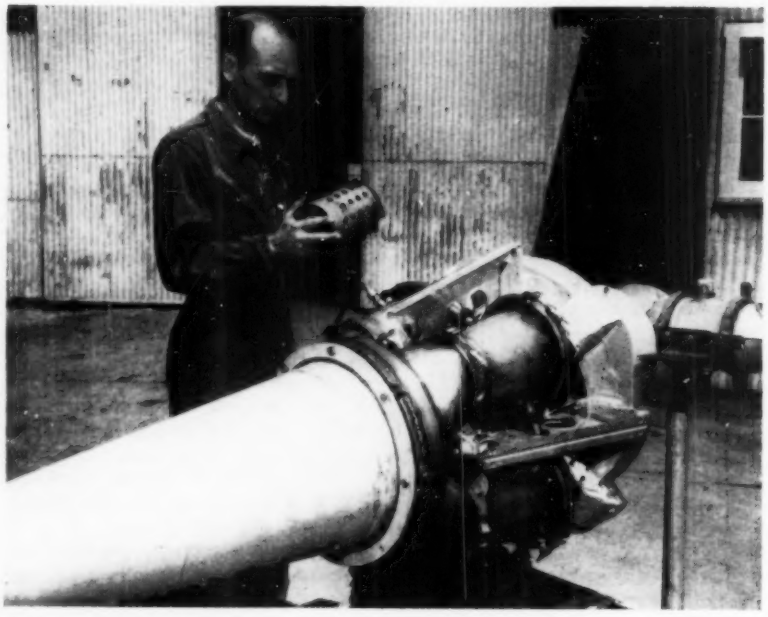
Further studies indicate that the transition temperature depends on many factors. These include chemical composition, manufacturing process, subsequent thermal and mechanical treatment and method of applying stress. Many of these are difficult to control. Therefore, concrete information about the effect of nitrogen, a controllable element, is extremely valuable in designing refrigeration equipment, military vehicles and equipment for use in the arctic, and aircraft that fly at high altitudes.



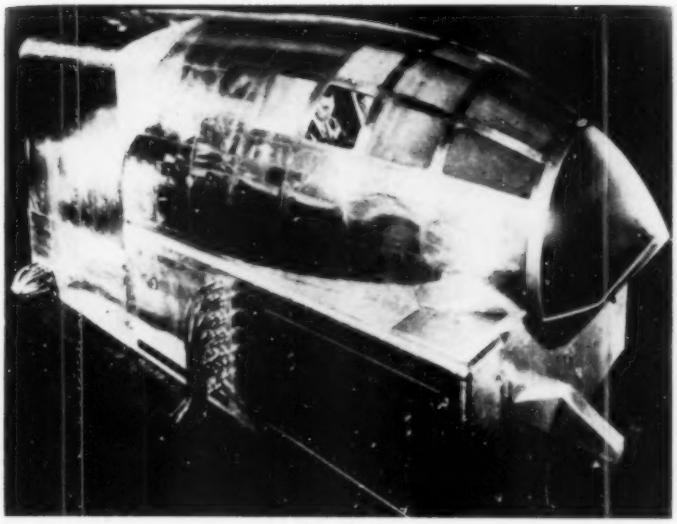
TRANSITION TEMPERATURE from ductile to brittle behaviour is lowered as the aluminum nitride content goes up. In this figure, solid curves in lower right corner indicate 1.6 percent manganese steels not treated with aluminum; open circles, 1.6 percent manganese steels treated with aluminum; triangles, 0.9 percent manganese steels treated with aluminum.

The low temperature increase in brittleness, or loss of toughness, is generally accompanied by a decrease in ductility; by a decrease in energy absorbed in fracturing; and by a change in appearance of the fracturing surface. Appearing fibrous in high temperature fractures, the surface becomes granular in fracture occurring at low temperatures.

Previous investigations into the effect of nitrogen on low temperature properties produced conflicting reports. Researchers found a beneficial effect, a detrimental effect, or no effect, as nitrogen percentages were increased. The NBS study explains the inconsistency of this previous data by determining that the effect depends on the chemical form in which the nitrogen is found, the amount of aluminum nitride, and not merely on the percentage of nitrogen contained in the steel.



THIS CENTRIFLOW JET ENGINE was developed by students at the Northrop Aeronautical Institute to power small private planes at speeds up to 300 MPH. Weighing 172 pounds and producing a thrust of 340 pounds, the engine has four combustion chambers installed parallel to the engine axis. While there are no immediate plans for production, Northrop will flight test the engine in the Ryan Navion.



ON THE OUTSIDE, there is no similarity between the simulator and a B-50. The former is a box-like structure, with only the front resembling the nose of an airplane. Beside it are four cabinets; one houses the power plant, three enclose analogue computers, servo mechanisms, and amplifiers.

INSIDE OF COCKPIT duplicates the cockpit of a B-50 exactly. Here pilot handles the controls in the simulator under take-off conditions. Co-pilot and flight engineer are trained at the same time.

Electronic Simulator Teaches Air Crews to Fly On the Ground

AN ALL-ELECTRONIC DEVICE that simulates in every detail the flight characteristics of the Air Force's B-50 is now training combat airmen. Using blind-flying techniques a pilot, co-pilot, and flight engineer take the airplane from pre-flight checks, through the warm-up, into the air and finally back to earth without leaving the ground. The simulator will do everything the airplane does—but fly.

Heart of the device are anologue computers, servo mechanisms and amplifiers. The servos and amplifiers continually solve differential equations relating to flight and engine power as an instructor sets up flying conditions. All the servos are related; many receive controlling impulses from five or six other units.

The insides of the simulator duplicate the airplane's cockpit exactly. There is a place for the pilot, co-pilot, and flight engineer, and all the instruments occupy the same positions as in the actual airplane. These operate and react just as they do in the B-50.

The instructor uses a trouble box to introduce emergency conditions. Induced troubles include icing conditions, engine failures, engine fires, fuel pump failures, cylinder head overheating, etc. Malfunctions are reflected by the proper instruments and unless the pilot or engineer takes corrective action the plane crashes. A red signal light in the cockpit indicates a crash.

If the crew fails to properly run through check lists, like the pre-flight or engine-stopping list, the device signals this fact to the instructor; indicating what step was omitted. Blind landings are made using radio and built-in Ground Control Approach.

Top Air Force training personnel are enthusiastic about the new simulator. They predict it will cut in half actual flying time required to check out a pilot in the B-50. And since it is not dependent on the weather, training can be given in it every day. The result will be more pilots trained with fewer airplanes required for training purposes.

In addition, if a new crew member makes a mistake, there's no damaged or destroyed airplane. By repeating the emergency conditions over and over again, the crew can be trained to react automatically to any unusual flying conditions.

Curtis-Wright Corporation built the simulator under the supervision of the Air Force's Wright Air Development Center Equipment Laboratory. Additional simulators are planned for the B-36 bomber and C-124, C-119, and C-97 cargo planes.

AEC Unveils Details of Largest Research Reactor

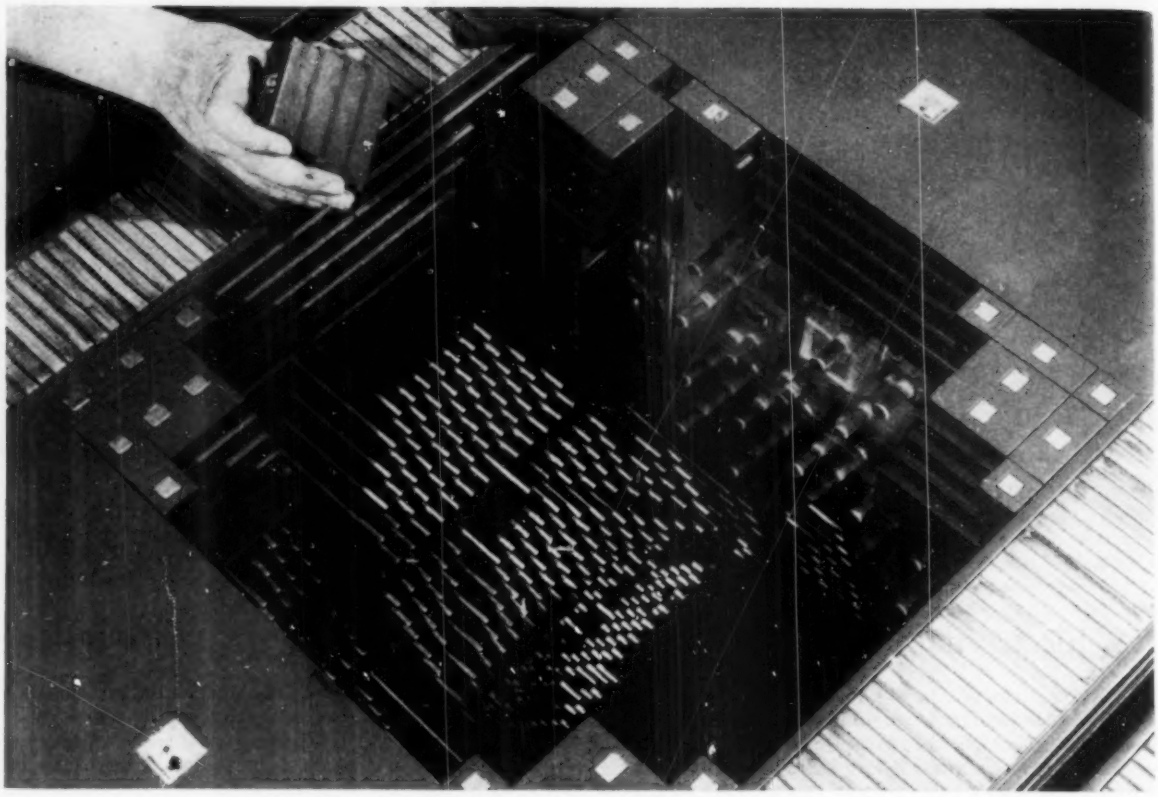
THE U. S. ATOMIC ENERGY COMMISSION has declassified certain construction and operating details of the low-power nuclear reactor at the Brookhaven National Laboratory. AEC designed this unit, largest of its type in the United States, for research and the production of radioisotopes for industry and the medical profession. Purpose of the declassification is to advance the art of reactor technology by making information available to industrial organizations concerned with changing atomic energy to electrical energy.

The reactor proper is a 25-foot cube made up of 60,000 pieces of graphite. A vertical split in the center of cube forms a gap for cooling fluid. Thousands of cubic feet of air are introduced and circulated through each half.

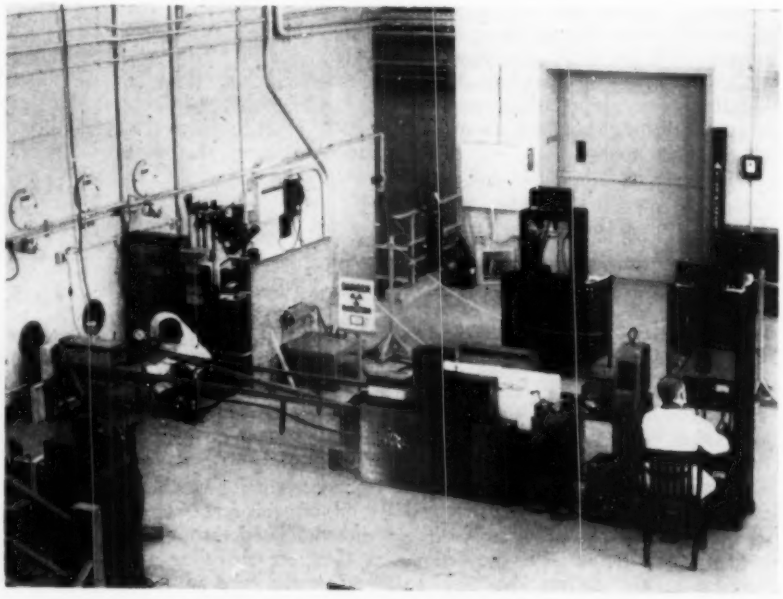
Concrete shielding five feet thick enclose the cube and chambers. This makes the reactor's length 55 feet, including shields, graphite and central air gap. The reactor's width is 38 feet, including shield graphite and center space.

Only the west face of the unit is available to all qualified scientific people (subject to approval by the director of Brookhaven and the AEC). The rest of the reactor is still off limits to all but those with AEC security clearances based on an FBI investigation (photos next page).

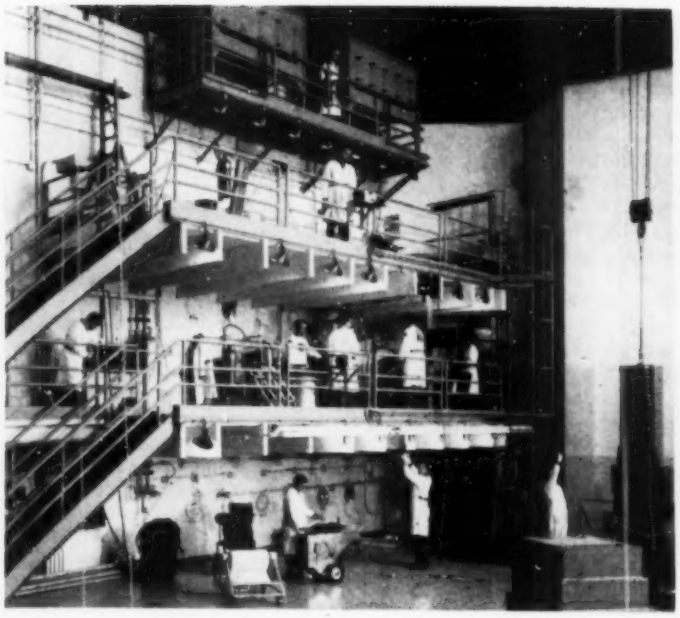
AEC Reveals Details of Brookhaven Nuclear Pile



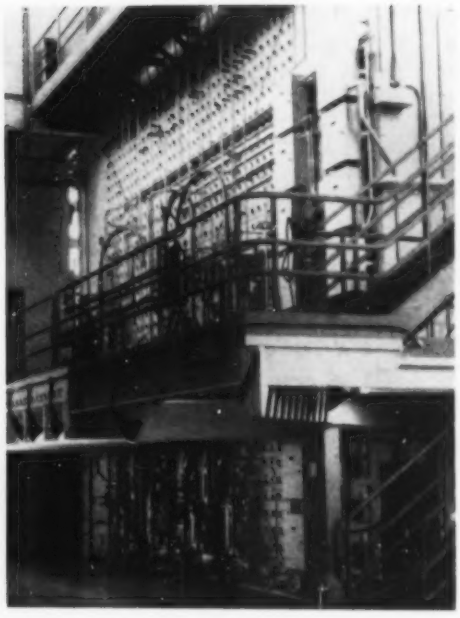
WOODEN MODEL OF THE NUCLEAR REACTOR, or "atomic furnace," at Brookhaven National Laboratory. The black area in the center, inside the shield, represents the graphite cube, the "housing" of the "furnace." The white rods in the cube represent aluminum cartridges which contain pure uranium metal, the "fuel" which "burns" or fissions, in the chain reaction of splitting atoms of uranium. The reaction releases atomic particles, known as neutrons, for use in experiments and for production of radioisotopes. The cube is enclosed in a shield of heavy concrete five feet thick. However, scientists can use slow neutrons which "leak" out of the graphite cube. The top is normally sealed off by the interlocking concrete plugs shown. Experimental equipment can be set up in place of one or more plugs. Reactor is largest of its type in the world.



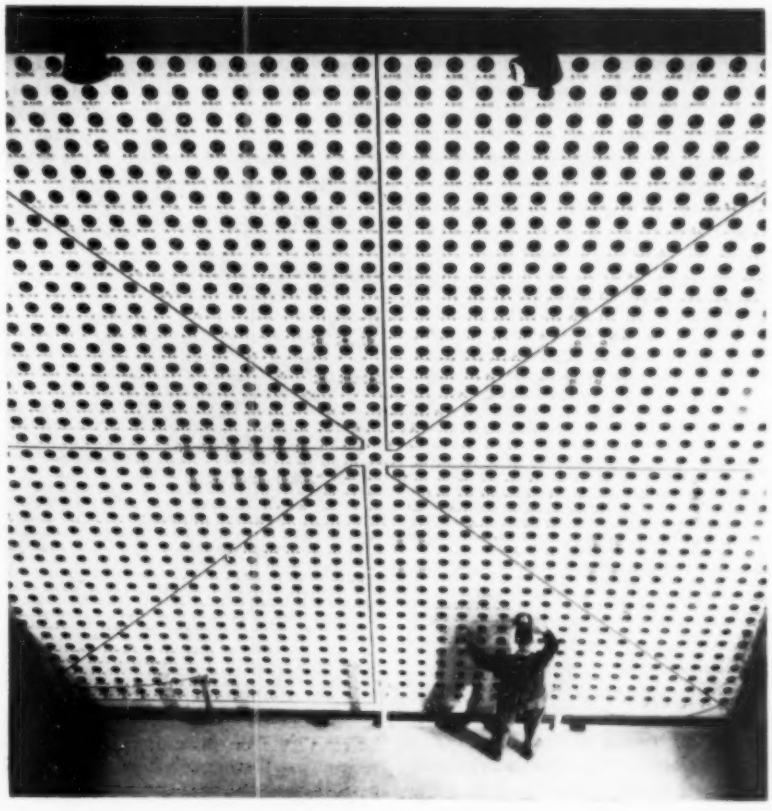
EAST FACE IS A RESTRICTED experimental area. Here beams of neutrons emerge through ports in the face for studies of the properties of neutrons themselves, or of materials they strike. In the center experiment, a beam of neutrons comes out of the reactor face, and is reflected by a mirror. Reflected neutrons are then detected by a bank of counters inside the shielded array (center). Neutron counts are recorded on the panel at right, which also supplies voltage for the counters. In the background, behind shielding, is a slow-neutron chopper. This instrument selects neutrons according to their speeds. It consists of fast rotating disks with openings arranged so that only neutrons of a certain speed will pass through; neutrons with different speeds are absorbed by the metal of the disks.



WEST FACE IS OPEN to all qualified scientific people. The security walls (far left and far right) seal the area off so that it can be used for experiments without revealing classified data from other parts of the structure. On the first balcony, physicists and chemists are performing typical experiments with spectroscopes for measuring the energies of neutrons in beams emerging from the reactor. The round ports or openings can be used either to let out such beams or for inserting substances to be made radioactive inside the reactor. On the ground floor and on the second balcony are health physicists with equipment for monitoring the ports, to make sure that background radiation is kept below tolerance levels. Reactor supplies isotopes to industry.



NORTH FACE CONTAINS A pneumatic tube system. A sample is inserted into one of the tubes above or below the long balcony, and sped into the reactor for bombardment by neutrons. It is returned, radioactive, for use in experiments. The system is useful in making radioisotopes of short half-life which lose their radioactivity in seconds, or minutes. Deliveries can be made directly into one of several adjoining laboratories, for use in connection with special experimental equipment.



SOUTH FACE IS THE LOADING FACE. Tons of pure uranium metal are loaded through the holes in this shielding wall into the graphite moderator to start a chain reaction. The rows of holes are eight inches apart and represent the arrangement of the uranium metal as it resides in the graphite moderator. The holes can also be used to insert certain types of metals and other substances to be irradiated by neutrons for industrial uses. The technician in the photo is standing on an elevator which enables him to move to any level of charging holes. He is using a periscope to view the handling of radioactive materials by remote control. A wall of heavy concrete five feet thick protects him from radiation given off by the reactor. Only the west face has been declassified. Remainder of the reactor is still off limits to all but those with AEC security clearances based on an FBI investigation. Purpose of the declassification was to advance the art of reactor technology by making this information available to industrial organizations concerned with the transformation of atomic energy to electrical energy.

I.R.E. Convention: Trend to Tubeless Units May Revolutionize Electronic Industry; Germanium Is The Key Word

ELECTRONICS, one of the fastest-developing fields of engineering, is on the verge of the greatest advancement since the development of the vacuum tube according to some industry observers. Over 27,000 electronic engineers saw signs of a new trend, tubeless components, at the 40th annual convention of the Institute of Radio Engineers. Half a dozen major electronic manufacturers featured the new devices in their displays; seven technical papers reported the latest developments.

Advantages being claimed for the new components are impressive. They include great savings in space and weight, longer equipment life with reduced maintenance costs, more rugged devices, and reduced power consumption because there are no filaments to heat.

The key word in tubeless units is germanium, the silver white metal that is a semi-conductor (its electrical properties are midway between an insulator and a conductor.) Germanium units that have already been developed are: diodes to replace vacuum tube diodes; area rectifiers; and transistors to replace vacuum tube triodes. Development on all units is proceeding so rapidly that authorities feel the future of tubeless elements is a wide-open field. And no one dares predict where it might stop.

One of the big stumbling blocks to this development was the preparation of germanium metal itself. A satisfactory method has finally been evolved to produce the metal with the purity that is needed. This is how it is done. Germanium oxide is recovered during the treatment of zinc and cadmium ores. Heating the oxide in a hydrogen atmosphere reduces it to the metal. In this state it is 99.993 percent pure—but this is not pure enough for use in tubeless elements. So the metal is cast in vertical ingots. The ingot freezes slowly from the bottom up and impurities concentrate at both ends, leaving the middle section extremely pure.

Germanium freezes into a poly-crystalline structure in the ingot. While this structure was formerly used for making diodes and transistors, it was not entirely satisfactory, because of disturbances formed at the crystal surfaces. Now single crystals are used. The crystals are grown by melting the pure middle section of the ingot and drawing a seed crystal from the melt. The lattices are oriented so that plane faces form along the side of the crystal. The use of single crystals has produced germanium devices that have extremely uniform characteristics.

The first germanium tubeless device was the diode. These have replaced vacuum tubes in army equipment and television sets to a limited extent since the end of World War II. But widespread application of diodes is now expected because of the successful development of transistors to replace vacuum type triodes. A transistor is usually used with from two to six diodes.

Two types of transistors have been developed. The point contact transistor uses a 0.02 in. thick wafer cut from a single crystal. These have some limitations, and researchers have been working on the junction type transistor. In this unit, which has just been successfully tested, the semi-conductor element is a thin wafer of germanium into which impurities have been diffused from opposite sides. Production of these units is expected to start this summer.

The junction type transistor has many advantages over earlier devices: they reduce noise levels, formerly a serious objection to the use of transistors; they operate at extremely high efficiencies; they permit large savings in space; they operate at very low ac power levels; and they use only small amounts of dc power.

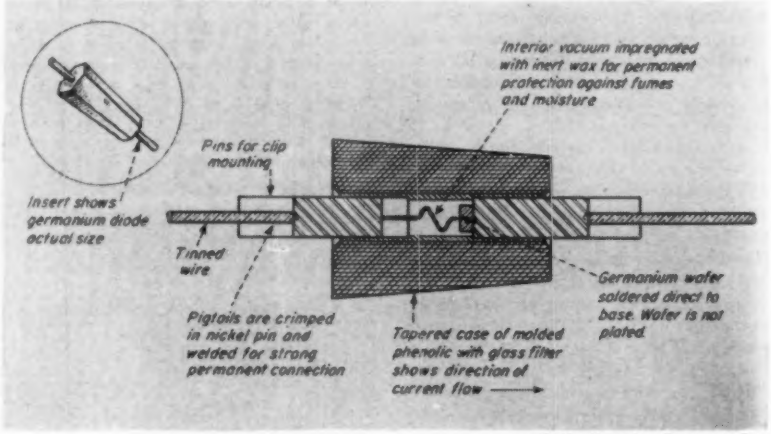
Enthusiasm for all these advantages has caused some engineers to go overboard making claims and counter-claims for junction type transistors. But at the present stage of development there are still some serious limitations. Most important of these is the fact that the junction transistor does not lend itself to switching operations. Frequency response is very low because the capacitance is high and thus its dc impedance is high.

But despite limitations, this is the picture predicted by germanium authorities: transistors and diodes will find their principal use, at present, in automatic computer circuits. By replacing vacuum tube diodes and triodes, the tubeless units will reduce the size of the computers considerably, and the character of germanium devices will make more uniform results possible. About 40 percent of the vacuum tubes used in radio and television sets will also be replaced as soon as production makes this possible. After that, it's anybody's guess.

Now, germanium diodes are about twice as expensive as vacuum tubes. But the price is falling as production increases and new suppliers enter the field.

Looking ahead, the biggest use of these tubeless devices may be in industrial control applications. Now such use is out because of the limited power capacity of diodes and transistors. But several authorities felt that future developments would make control equipment one of the largest users of tubeless units. The advantages of tubeless industrial control equipment are obvious: more rugged equipment; reduced maintenance; smaller size, etc.

Here is one indication of how rapidly germanium research is progressing. It had been agreed that diodes and transistors cannot be interchanged directly with vacuum tubes. Because of the characteristics of the devices,


Interior vacuum impregnated with inert wax for permanent protection against fumes and moisture
Pins for clip mounting
Insert shows germanium diode actual size
Tinned wire
Germanium wafer soldered direct to base. Wafer is not plated
Pigtails are crimped in nickel pin and welded for strong permanent connection
Tapered case of molded phenolic with glass filler shows direction of current flow

Radio Receptor Company, Inc.

CROSS SECTION OF a typical germanium diode shows the simplicity of the device. Extensive use of this unit will be made in automatic computers and radio and television sets. Total length from pin-end to pin-end is less than one inch. Other germanium devices that have been developed are area rectifiers and transistors.

the circuits must be designed especially for tubeless units. But Signal Corps scientists reported to the I.R.E. that they had developed, with Bell Telephone Laboratory's help, a radio teletype converter which used transistors throughout—and these were interchanged with vacuum tubes without circuit changes. The resulting device weighed ten pounds, as compared with the vacuum tube radio teletype converter which weighed one hundred pounds.

Use of Magnetic Amplifiers Is on the Rise

Tubeless magnetic amplifiers are in for increased demand. The military are interested in these devices because they make rugged electronic control. One I.R.E. exhibitor displayed a motor speed control that used no vacuum tubes or relays. Selenium rectifiers and a magnetic core replaced the vacuum tubes. In this display, a dc motor was operated from an ac power supply—disc rectifiers converted the ac to dc. At any load up to full load, the magnetic amplifier kept the speed constant by changing the voltage applied to the motor armature.

Defense Department Divides Electronic Responsibility

WASHINGTON—The electronic production resources agency is assigning to each of the military services the responsibility for providing production capacity for a group of components needed for defense.

The responsible service will develop a program for its particular components, based on the estimated number needed by the combined services, target dates for the program and target dates for which expansion and know-how will be available. It does not actually buy but it arranges for plant expansions and assignments.

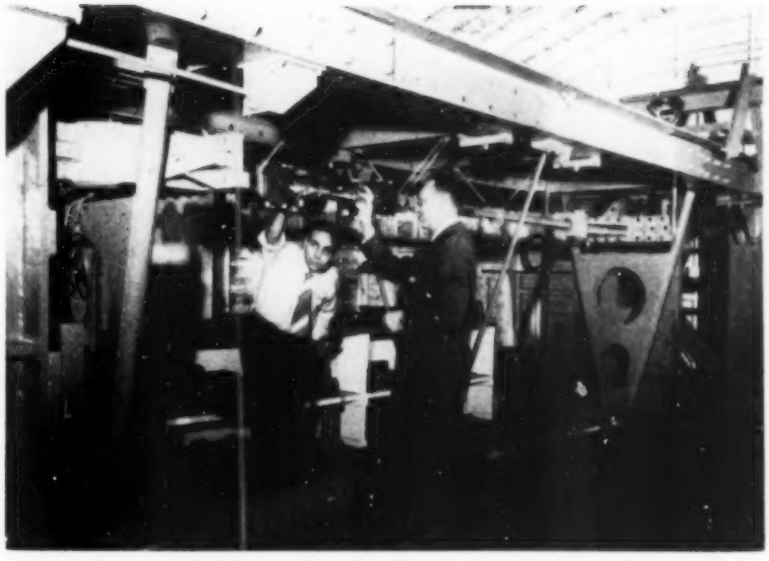
Requirements for certain components are handled by this service, no matter where the contract originated. The manufacturer who is having production difficulties should go to the service handling the components, for help, not to the one contracting service.

These are the products each service will handle:

Air Force—High temperature wire, relays, fixed and variable wound resistors, switches, thermistors, acorn tubes, cathode ray tubes, gas switching tubes, klystrons, magnetrons, pool cathode tubes, strobotrons and flash tubes, thyratrons (excluding hydrogen thyratrons).

Army—Flat press subminiature tubes, glass and GT receiving tube types, hydrogen thyratrons, crystal diodes and transistors, meters, quarts crystals, resistors—accurate film types sockets, connectors, and plugs.

Navy—All button stem subminiature (except fuse tube types), metal receiving tube types, miniature tubes, phototubes, power tubes (including vacuum and mercury vapor rectifiers), UHF power and transmitting tubes, capacitors, dry rectifiers, fixed and variable composition resistors, transformers.



LOCKHEED RESEARCH ENGINEERS prepare to fatigue test transport landing gear piston in new 500,000 lb machine. Pressure comes from two sources, a cylindrical hydraulic jack on floor and a rotating unbalanced weight in steel structure at left.

Powerful Fatigue Tester Exerts 500,000 Pound Force

THE MOST POWERFUL FATIGUE TESTING MACHINE ever built applies forces up to 500,000 pounds to test design safety factors applied to airplane parts. Developed by research engineers at Lockheed Aircraft Corporation, the new device can test parts up to 12 feet long and five feet wide.

Differing from other inertia loaded fatigue testers, it uses a moving instead of a static reaction to avoid driving its full force into the building foundation. Force is supplied by a hydraulic jack and an unbalanced rotating weight.

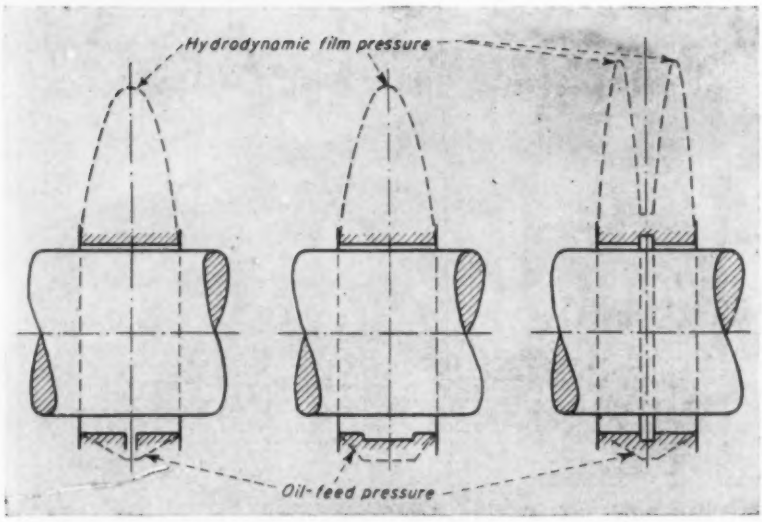
Main parts of the machine include a steel girder framework from which the pressure-applying apparatus is suspended; two heavy beams assemblies suspended by flexible mountings from both ends of the overhanging frame; an electric powered rotating unbalanced weight in one beam assembly; and a horizontal hydraulic jack interconnecting the beam assemblies at their lower ends.

In operation, a fixed or preliminary force is applied by the hydraulic jack which squeezes the two beam assemblies against the specimen with a force up to 250,000 pounds. Then the weight is rotated; applying an additional force equal to that of the jack. Mechanics of the machine cause the total force to alternate compression and tension from 5 to 2000 times per minute while strain gages attached to the part measure the applied force.

GE Predicts Wider Use of Ceramic Transmitting Tubes

Wider use of ceramic-and-metal transmitting tubes was predicted at the I.R.E. Convention by John E. Nelson of the General Electric Company. Nelson said that glass is no longer adequate for envelopes of the high-power, high-frequency tubes being used in many applications today.

He claims these major advantages for ceramic-and-metal tubes: resistance to shock and vibration and lower electrical losses. Also, this material permits higher temperatures in the exhaust process to produce a superior vacuum.



HOW OIL PRESSURES ARE distributed in plain journal bearings that are fed by an oil hole (left) and an axial groove (center) and a circumferential groove (right). NBS studies indicate that rate of oil flow is affected by these pressures.

Oil Flow in Plain Journal Bearings Analyzed

A SIMPLIFIED METHOD of analyzing the rate of oil flow in plain journal bearings has been developed by the National Bureau of Standards to aid in the study of bearing design and operation. The researchers attempted to find the factors involved in supplying an adequate oil flow to maintain a load carrying film and to dispose of frictional heat developed in the bearing.

Two factors were found affecting the flow of oil from the ends of plain journal bearings fed through an oil hole, an axial groove on the unloaded side, or a circumferential groove: one results from the oil feed pressure; the other involves the hydrodynamic-film pressure supporting the load. In bearings with a circumferential groove, the flow due to the hydrodynamic-film pressure is negligible in comparison to that due to oil-feed pressure. But in the other two types of bearings, both factors cause appreciable flow.

NBS scientists postulated that the rate of oil flow is the sum of two components: the flow rate caused by the oil feed pressure; and the flow rate produced by the hydrodynamic-film pressure supporting the load. Also, for any given type of oil-feed design, the two components are related to bearing dimensions and operating variables. This relationship is expressed in dimensionless equations:

$$\frac{Q'\mu}{pC^3} = \Psi_1\left(\frac{D}{C}, \frac{C}{L}, \frac{\mu N}{P}\right)$$

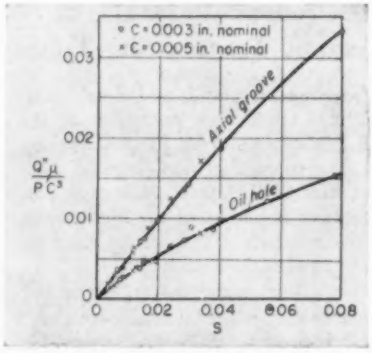
$$\frac{Q''\mu}{pC^3} = \Psi_2\left(\frac{D}{C}, \frac{C}{L}, \frac{\mu N}{P}\right)$$

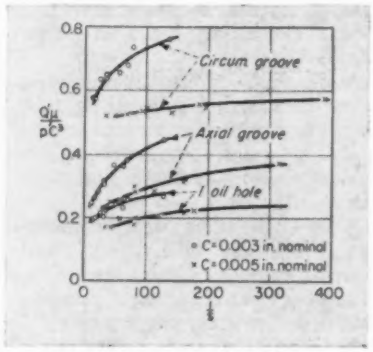
Where Q' = flow rate due to oil feed pressure; Q'' = flow rate due to hydrodynamic film pressure; μ = absolute viscosity of the lubricant at atmospheric pressure and bearing temperature; p = oil feed pressure; P = load per unit projected bearing area; N = speed of journal; D = journal diameter; L = bearing length; and C = diametral bearing clearance.

The functions ψ_1 and ψ_2, which depend upon the oil-feed design of the bearing, were determined experimentally for the three basic designs mentioned. The results are illustrated graphically by plotting the parameter Q'' against the sommerfeld number, $S = (\mu N/P)\ (D/C)^2$, and plotting Q' against the reciprocal of the sommerfeld number.

To obtain this information, it was necessary to separate the observed total oil flow into the two components. Separation was done by plotting $Q\mu$ against p for constant values of $\mu N/P$. On this graph, the data for each value of $\mu N/P$ falls on a straight line, the slope of which is equal to $Q'\mu/p$. The intercept at p = o is $Q''\mu$.

Results indicate that there was good correlation of the parameter Q''/pC^3 with Sommerfeld number at different bearing clearances. The differences obtained for bearings of different clearances when plotting $Q'\mu/pC^3$ against the reciprocal of sommerfeld number are caused by bearing out-of-roundness, the result of deformation under load.





EFFECTS OF DESIGN on rate of oil flow caused by hydrodynamic pressure (left) and oil feed pressure (right) are illustrated here. Graph at left shows hydrodynamic pressure effects are nil in circumferential grooved bearings.

Organic Chemical Replaces Soaps in Wide-Range-Temperature Greases

GREASES SUITABLE FOR USE at temperatures ranging from minus 80 to plus 400 F have been developed by the Naval Research Laboratory. In addition, the new lubricants stand up in storage much better than conventional greases.

NRL scientists replaced the soaps of fatty acids, usually used to gel lubricant fluids, with copper phthalocyanine, a blue organic compound. This can withstand heat and oxidation. In the past the soaps have caused the deterioration of greases in storage. And they lose their ability to gel at temperatures above 230 F.

Four different types of greases have been developed: copper phthalocyanine with: 1) silicone fluid bases, 2) with petroleum or synthetic oils, 3) with synthetic diester oils, and 4) with fluorocarbons.

The silicone fluid greases have performed consistently at temperatures of 480 F. The greases with petroleum

or synthetic oils have excellent storage properties. Using synthetic diester oils with the phthalocyanine compound produced a grease that may permit lifetime lubrication of instruments, fire control equipment, and electric meters. By using certain fluorocarbons, scientists produced greases usable in the range from 32 to 480 F. Low temperature experiments have also been successful.

Development of these new greases has stimulated research into the use of tool steel or high chromium steel for ball bearings that will stand these high temperatures for long periods of time.

Reflection Plotter Helps Avoid Collision At Sea

BY PROVIDING SHIPBOARD RADAR with a visual course and speed recording feature, a reflection plotter developed by Ratheon Manufacturing Company permits the ship's navigator to keep track of all vessels within danger range and to plot the course of those likely to cross or overtake his own vessel. Members of the crew do not have to remember the location of other ships because they can plot the maneuvers of other vessels right on the face of the radar scope.

The reflection plotter provides a plotting surface made of non-reflecting plastic which fits right over the radar screen. Edge-lighting around the plotter illuminates any objects placed in contact with it so that marks made on the plotter by a grease pencil become luminous. Other optical arrangement makes these notations appear as if they actually were on the radar screen.

Radar pips caused by the presence of other ships are marked and their movement followed to determine the direction and speed.

Plastic Dies Stamp Out Aircraft Parts

COST REDUCTIONS ranging from 25 to 75 per cent are claimed by Lockheed Aircraft from the use of phenolic plastic in place of Kirksite die metal. In the past two years, the company has produced 200 dies using 107,000 pounds of plastic instead of 1,900,000 pounds of scarce kirksite.

Savings in toolmaking time and weight of fixtures have also impressed manufacturing specialists. One die weighing 17½ tons in kirksite was made of plastic in half the normal time and weighed only 3,500 pounds.

Lockheed reports these dies have virtually unlimited life span (for aircraft purposes) and can be easily repaired if they crack.

Parts being turned out with the phenolic dies include an airplane nose skin, Fiberglass radomes five feet in diameter, and 14 feet one-piece liners for the nose doors of P2V's. Plastic is also being used to make double-action draw dies and drill jigs.

Strain Measuring Technique Is Simpler, More Sensitive

ENERGIZING conventional strain gages with high voltage pulses instead of d-c current has tripled the sensitivity of aircraft propeller strain measurements in a new method developed for the Air Force by scientists of the Illinois Institute of Technology.

Changes in electrical resistance of the gage wires as they are stretched during propeller operations are picked up by slip rings and fed into a specially designed amplifier containing 107 vacuum tubes. By connecting the gages in series, the number of slip rings has been reduced 50 percent.

WORLD'S LARGEST THERMOPLASTIC molding has been produced by Amos Molded Plastics. A complete refrigerator door-liner with molded-in shelves, butter compartment, and egg racks, it is five feet wide, 38 in. high, 22 in. deep and weighs seven and a half pounds. Advantages of the molded liner over formerly used materials include: reduction of overall weight, better insulating qualities, conservation of critical materials used in porcelain enameled steel, and greater resistance.

INDUCTION AND DIELECTRIC HEATING EQUIPMENT manufactured before July 1947 must be certified by the FCC before June 30, 1952. The certificate indicates compliances with FCC rules and regulations Part 18 concerning radiation and interference of this equipment. Copies of the regulations may be obtained from the Government Printing Office, Washington, D. C.

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MAGNE-PROBE is a new instrument for detecting wear spots in aircraft exhaust systems caused by heat corrosion. It operates on the principle that the badly scaled and brittle areas become permeable to magnetism. And the permeability of stainless steel and inconel alloys increased in direct relation to the change in crystal structure caused by excessive heat. An extremely sensitive and stable bridge, the instrument measures the inductance of a coil whose core is the structure being tested. Since the inductance of the coil is proportional to the permeability of the core material, a measure of the heat corrosion of the structure is obtained. The device was developed by Max Brodofsky of Pan American Airways and is being built by the American Instrument Company.

•

FIRST AUTOMOBILE BODIES made of plastic are being built by the Glasspar Co. for custom built sports cars. Made of U. S. Rubber Vibrin polyester plastic and layers of glass fiber, the body is molded in one piece, $\frac{3}{16}$ of an inch thick. It is claimed the body is dent-proof, rust-proof and it will hold paint well. Heavy impacts, such as occur in accidents, cause the material to crack. These cracks can be repaired with a patch of glass fiber and plastic in less than one hour.

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SHOCK WAVE PATTERNS beyond the sonic barrier will be studied on a new water table developed and constructed at the University of Tennessee. Capable of producing data on effects of speeds as high as 2,500 mph, the apparatus will be used primarily to gather qualitative information on wave patterns set up by supersonic jets and guided missiles.

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THE AMERICAN SOCIETY FOR TESTING MATERIALS has announced the establishment of an annual H. W. Gillet Memorial Lecture to be delivered each year at a meeting of the Society; the first to be given at ASTM's 50th Anniversary Meeting in New York.

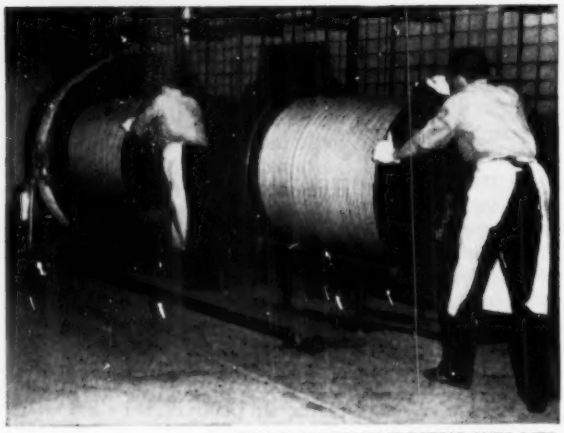

PHOTO COURTESY ELECTRIC AUTO-LITE

Hundreds of thousands of feet of Silastic insulated cable are now produced every week by various wire and cable companies. Sizes range from No. 22 to 500,000 circular mils. Applications range from wiring for the new House of Commons to ignition cable for Army ordnance vehicles and Navy control cable.

Silastic insulated wire and cable is in full scale commercial production now because Silastic retains both its physical and its dielectric properties at temperatures ranging from below —70° to over 500°F. Shock and vibration, hot oil, oxidation, corona, outdoor weathering and the mere passage of time have little if any effect on the properties of Silastic. With high thermal conductivity and good dielectric properties over a wide range of frequencies and at both high and low voltages, Silastic is unique among electrical insulating materials for traction motors and Banbury mixer motors as well as wire and cable. And no other resilient gasketing material is serviceable over so wide a temperature span or in contact with oil at such high temperatures.

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LOS ANGELES
WASHINGTON, D. C.

In Canada: Fiberglas Canada Ltd., Toronto
In England: Midland Silicones Ltd., London

Fluid Flow Through Orifices

RAYMOND J. NOVOTNY
Research Engineer, Reaction Motors, Inc.

ON PAGES 215 and 217 are nomographs for determining the factors involved in the flow of fluids through orifices.

Nomograph No. 1 is designed to solve the following equation for any one of the variables providing the other four are known, considering nd^2 as a single variable.

$$W = 0.526\, C_D\, (nd^2)\, \sqrt{\rho}\, \sqrt{\Delta P}$$

where

W = fluid flow (lb per sec.)
C_D = orifice discharge coefficient
n = number of orifice holes
d = diameter of orifice holes (in.)
ρ = density of fluid (lb per ft³)
ΔP = pressure drop across orifice (psi)

INSTRUCTIONS FOR USE:

To find:

W:—Draw a line from point on density scale ρ to the known value on the ΔP scale. From the interesection of line ρ—ΔP with index line B extend a line to the correct point on nd^2 scale and note the intersection with the index line A. Through this intersection extend a line from C_D scale to the W scale and read the desired value.

C_D:—From the density value on the ρ scale extend a line to ΔP and mark the intersection on index line B. Draw a line from the intersection on B to the nd^2 scale and note the intersection on index A. Extend a line through the intersection on A from value on W scale to C_D scale.

nd^2:—Draw a line from C_D scale to W scale and note the intersection on index line A. From the density value of the fluid on ρ draw a line to desired point on ΔP scale and mark the intersection on index line B. Connect the points on A and B with a line and read the required value on the nd^2 scale at the intersection.

n or d:—First find nd^2 and then draw a line from a value on the n scale through nd^2 and read the corresponding value of d at the intersection on the d scale. To find n, first find nd^2 and reverse the process.

ρ:—Connect C_D and W values with a line and note intersection on Index A. From this point on A draw a line through nd^2 value to intersect index line B. From ΔP draw a line through B to cross the ρ scale at the desired value.

ΔP:—Extend a line from C_D to W. From where this line intersects index line A draw a line through the known point on nd^2 and note the intersection on index line B. Starting at the ρ scale extend a line through the intersection point on B and read the required value on ΔP scale.

EXAMPLE:

To find diameter (d) of orifice holes for the following conditions:

W = 15 lbs/sec.
C_D = 0.75
ρ = 31.2 lb/cu ft (s. g. 0.500)
ΔP = 100 psi
n = 20

From 0.75 on C_D scale to 15 on W scale draw line and mark intersection (0) on index line A. From density value 31.2 on ρ scale extend line to 100 on ΔP scale and mark intersection (X) on index line B. Draw line O-X and note intersection (M) on nd^2 scale. From number of orifices (20) on n scale extend a line through M to intersect d scale where diameter of orifice holes may be noted.

Answer:—0.186 in. dia.

Diameters greater than 0.250 in., may be computed algebraically from the nd^2 reading.

This nomograph also includes provisions for solving the equation

$$\Delta P_v = \frac{\rho v^2}{2g \times 144}$$

where:

ΔP_v = pressure drop across orifice, psi
v = ideal fluid velocity through orifice in ft. second.

Instructions for use:—

Extend a line from ρ to ΔP_v scales and note the intersection on the v scale. This single line process can be used to solve for any one of the factors in the above equation.

The nomograph No. 2 is designed for quick determination of the variation in pressure drop across orifices caused by production tolerances and was plotted from the following expression:

$$1 \pm \frac{e_{\Delta p}}{100} = \left[\frac{1}{1 \pm \frac{e_{\Delta d}}{100}}\right]^4$$

where

$\mp e_{\Delta p}$ = percent of change in pressure drop

$\pm e_{\Delta d} = \pm \frac{t}{d} \times 100$

t = tolerance in inches
d = orifice diameter in inches

TO FIND PERCENT OF CHANGE:

Draw a line from orifice diameter value on scale A through tolerance value on scale B and note intersection on $e_{\Delta p}$ scale. If tolerance is minus, the percent of change will be plus. If tolerance is plus, the percent of change will be minus.

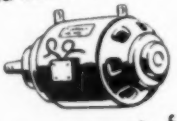
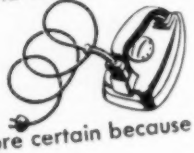
EXAMPLE:

dia of orifice = $0.020^{+\ .002}_{-\ .000}$ in.
pressure drop across 0.020 orifice = 100 psi
from nomograph $e_{\Delta p} \leqq -32\ \%$

Change in pressure drop caused by tolerance $= \frac{-32}{100} \times 100$ or —32 psi. through the hole.

(continued on page 215)

The right wire for the right job...

Technological advances in many industries constantly require new developments and new applications of wire and cable. A space-saving wire design has made possible smaller, more compact  motors. A new and better form of heat resistance in turn prevents failure in generators. Again, if a sharp turn can be given a wire, a new and better clock may be possible. New abrasion characteristics  may mean milady's iron won't fail. A city's safety is made more certain because a solenoid sets new records in performance. As simple a thing as better shielding in a wiring harness can be the secret of clearer radio and television reception. Auto-Lite Engineers, drawing on their many years of automotive experience, can answer such problems. For more complete information on the "right wire for the right job" write on your company letterhead to

THE ELECTRIC AUTO-LITE COMPANY

Wire and Cable Division

Port Huron, Michigan • Hazleton, Pennsylvania

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wire and cable
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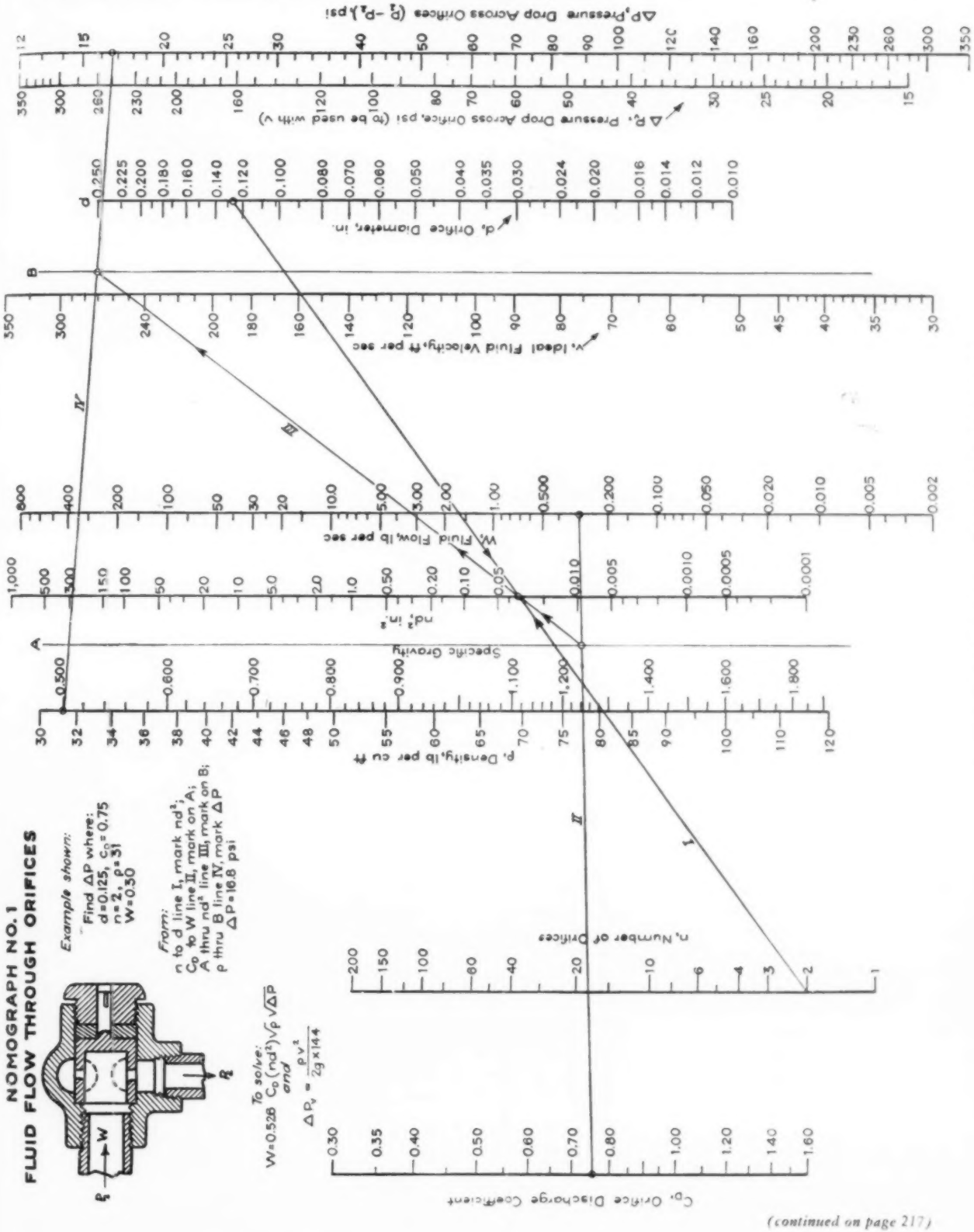
thermometers

Fluid Flow Through Orifices (continued)



(continued on page 217)

HOW TO KEEP "STAINLESS" IN YOUR PRODUCTS

This sink strainer is an excellent example of Armco 17 coming to the rescue when 18-8 went under government restrictions. The other familiar parts shown are also of Armco 17. They illustrate uses and drawing operations well suited for this grade.

Wash Basin

Automobile Gravel Guard

Drinking Fountain Top

Mess Tray for Armed Forces

Armco 17, Type 430 chromium stainless steel is available as an "alternate" for many jobs in which the use of 18-8 is restricted by NPA Order M-80. This government regulation affects only the nickel-bearing stainless steels such as Armco 18-8, Type 302.

Non-nickel-bearing Armco 17, with 14 to 18 per cent chromium, is one of the oldest standard stainless steel types. It is not likely to be as satisfactory as 18-8 for most equipment used in food processing, meat packing, dairies, textile wet-processing, or the manufacture of pulp. But Armco 17 has given an excellent account of itself in products not subject to unusually severe corrosive conditions. It is also suitable for heat-resisting uses up to about 1550° F. Type 430 has long been used for automotive trim and other decorative applications on refrigerators, ranges and washing machines.

Armco 17 sheets, strip and plates come in the same gages, sizes and finishes as 18-8, and there is a full range of bars and wire.

Forming characteristics are about the same as hot-rolled steel but welds are less ductile and less resistant to severe shock loading. With modifications in drawing practice, Armco 17 will take difficult deep-drawing operations. Bars and wire are readily machinable at higher speeds than 18-8.

Your Armco Distributor has Type 430 sheets in stock. He will be glad to supply you with technical information and fabricating data bulletins. If you do not know his name, write us at the address listed below.

ARMCO STEEL CORPORATION

1342 CURTIS STREET, MIDDLETOWN, OHIO • PLANTS AND SALES OFFICES FROM COAST TO COAST • EXPORT: THE ARMCO INTERNATIONAL CORPORATION

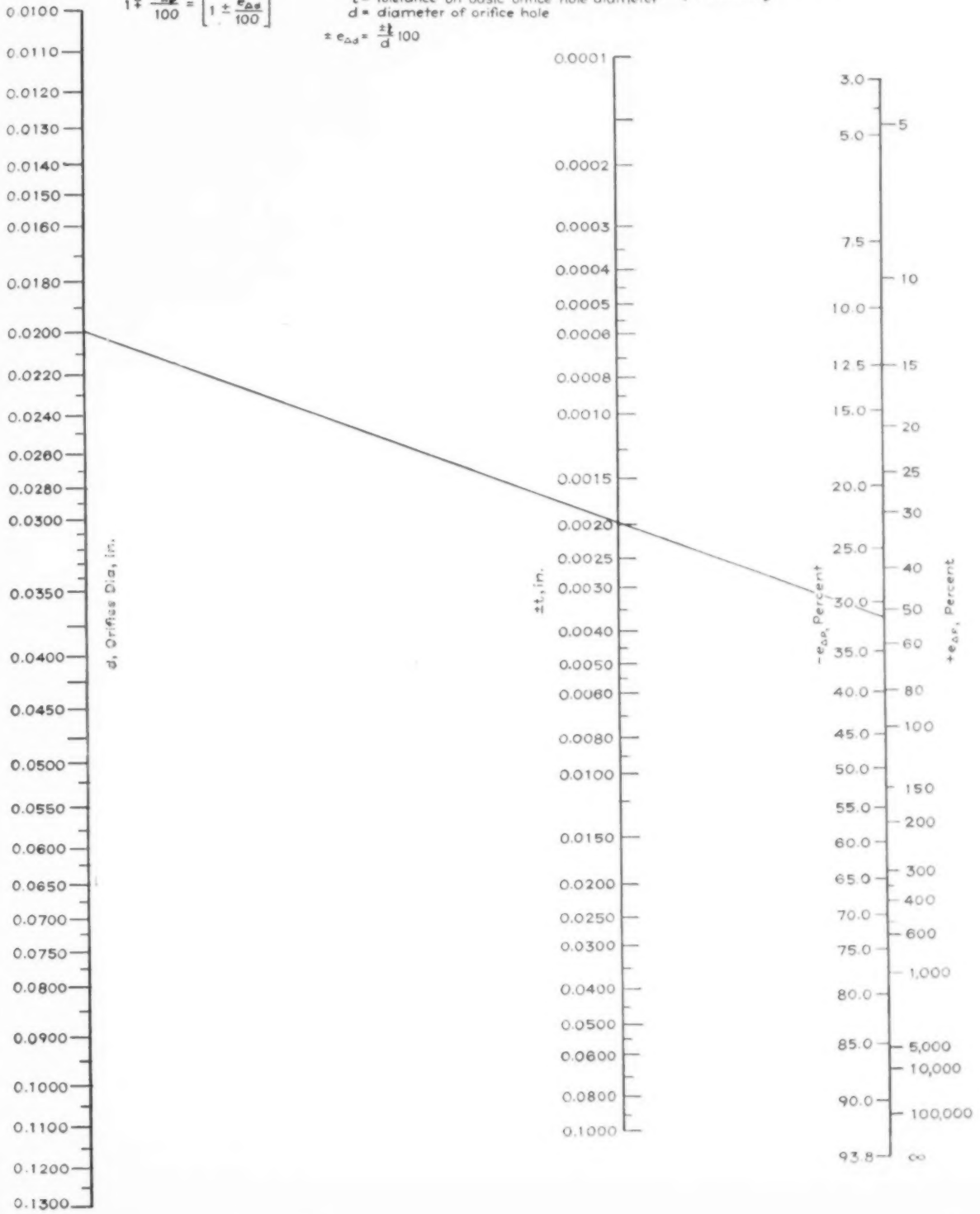
Fluid Flow Through Orifices (continued)

NOMOGRAPH NO. 2—EFFECT OF PRODUCTION TOLERANCES ON PRESSURE DROP ACROSS ORIFICES

$$1 \mp \frac{e_{\Delta p}}{100} = \left[\frac{1}{1 \pm \frac{e_{\Delta d}}{100}}\right]^4$$

$\mp e_{\Delta p}$ = Percent change in orifice pressure drop [(−) decrease, (+) increase] due to "t"
t = tolerance on basic orifice hole diameter
d = diameter of orifice hole

$$\pm e_{\Delta d} = \frac{\pm t}{d} 100$$



Smaller, Lighter, More Versatile Fractional Horsepower Motors

Having improvements in size and weight, usability, and appearance, a new line of fractional horsepower motors, designated as Form G, incorporates many different design features. According to the manufacturers, the form G motor weighs as much as 50 percent less per horsepower than the models it replaces, and is smaller in size. In addition, its field of application has been increased, and its appearance modernized.

The motors are available in open dripproof and totally enclosed fan-cooled models in types K (polyphase), KC (capacitor start), KH (split phase), and KCP (permanent split capacitor). These have a variety of applications such as: pumps, fans, blowers, compressors, office and home appliances, and motorized tools of all types.

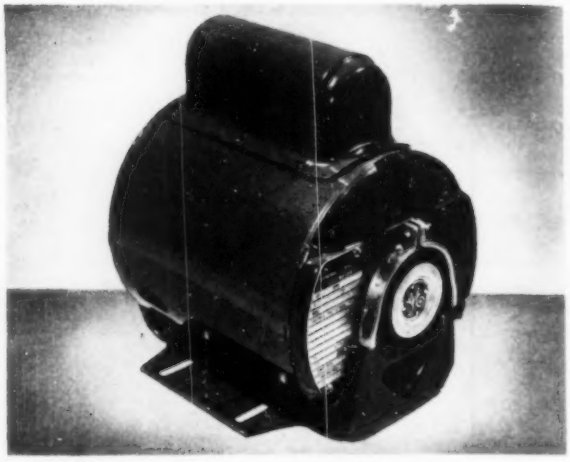
The reason given for the lighter weight and smaller size is a balanced electro-thermal design, plus more effective ventilation, and a greater use of aluminum for structural parts. The aluminum rotor winding is made by a vacuum-pressure casting process which produces a denser winding, resulting in more uniform performance. Large ventilating fins, cast integrally with the winding, give a maximum amount of air flow within a relatively small space.

An easily removed locking device holds the rotor in place. This device, together with the thrust-washer assembly maintains correct end play, absorbs moderate thrust loads, and requires no maintenance. In the resiliant base motor, a double bonded resilent ring is pressed on each bearing nose, and the motor held in the base by the formed latches. On solid-base motors, this resilient ring is omitted and the latches clamp the base directly on the bearing nose.

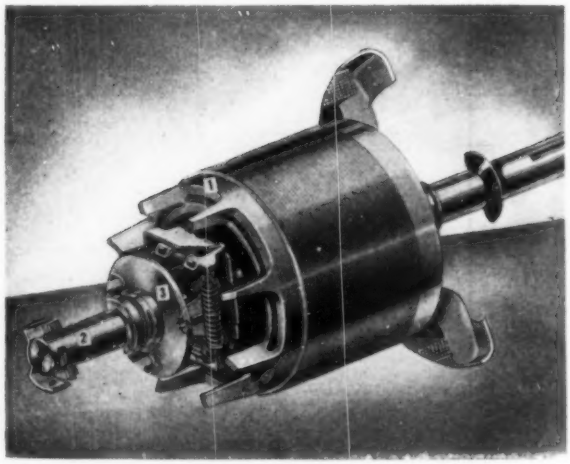
Also made of aluminum are the flat disk type end shields, ribbed and reinforced for extra strength to withstand the stresses of radial and end-thrust loads. The steel stator shell is lightweight but strong, with its surface phosphatized for corrosion protection.

The motors have NEMA standard mounting dimensions and interchange with single phase form G motors. For flexibility in mounting, the motor can be rotated approximately 100 deg from normal in either direction by unfastening the formed latches at each end of the motor. This also brings up the feature of the motor's ability to operate in any position with the shaft horizontal, vertical, or at any other angle.

The lubrication system was designed with a special sleeve and thrust bearing, in which provision was made for complete oil retention and recirculation regardless of the position of the bearing or the direction of the load. Oil capacity of these bearings is said to be more than 50 percent greater than the present designs. The totally enclosed fan-cooled as well as the dripproof models of the motor are built in both sleeve-bearing and ball bearing general purpose types. The ball bearing construction, for extra heavy thrust loads,



SHOWN ABOVE is the ½ hp, open dripproof, capacitor-start form G motor, having all-angle sleeve bearings. It weighs 50 percent less per horsepower than the models it replaces.



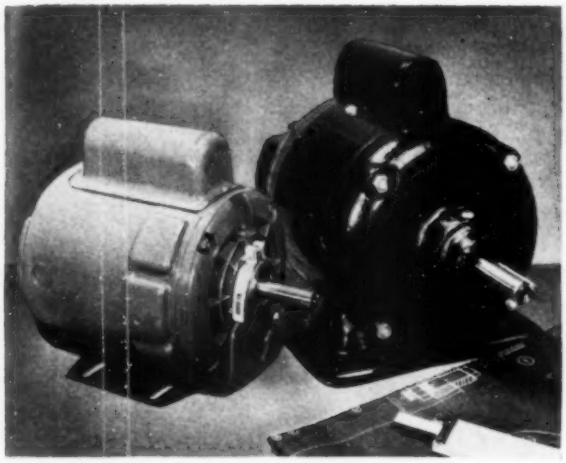
THE VACUUM PRESSURE CASTING PROCESS used to make the aluminum rotor, produces a denser winding. The locking device, 2, keeps rotor in place, maintains correct end play.

is protected by a large grease supply, easily refilled without disassembly of the motor.

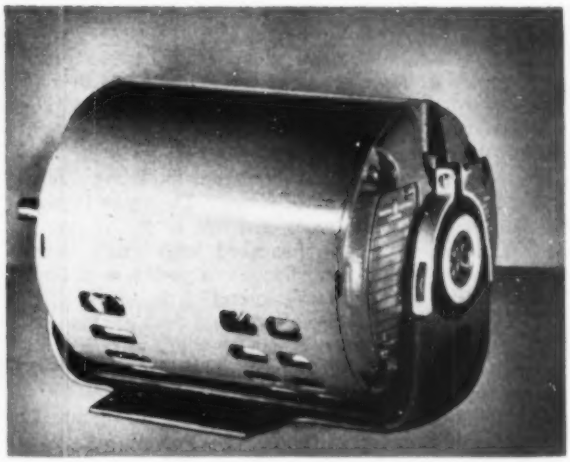
The new insulation system in the motor is said to withstand moisture, oils, mild acids and alkalies, and aging. However, no cellulose, or other natural insulating materials have been used. Nylon is used in slot and between-phase insulation and wedges. Wire insulated with Formex is used in the windings, and a red glyptal varnish is baked on the entire stator assembly. Split-phase motors, requiring more heat-resistant material in the starting winding, have glass insulated wire added for additional safety from burnout. A terminal board of textolite supports the connection terminals, automatic reset overload protective device

MATERIALS - PARTS

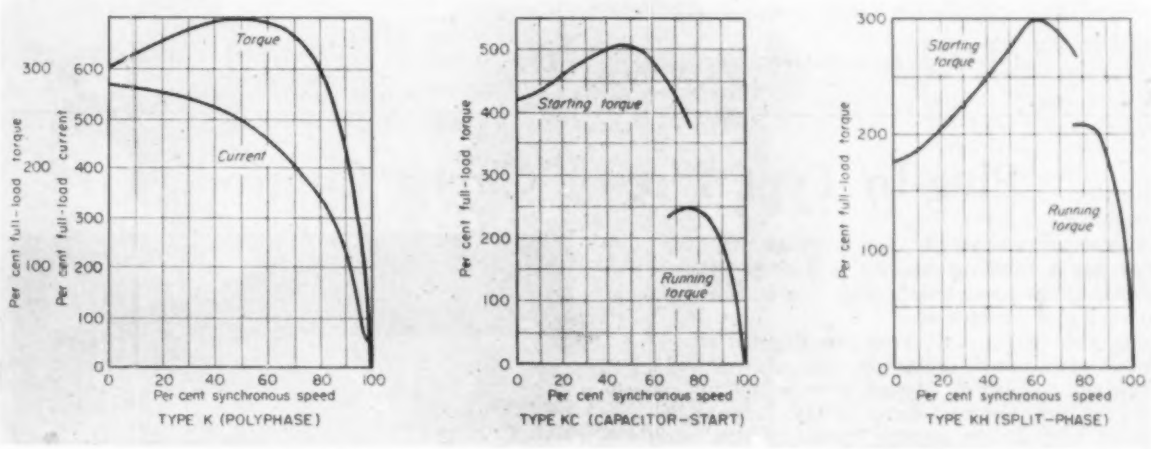
SPECIFIED BY PRODUCT ENGINEERS



THE TOTALLY ENCLOSED, fan-cooled form G motor (left) is compared with its predecessor of the same rating. The new motors often weigh less than half the motors they replace.



THE TYPE KH, split-phase, fractional horsepower motor has a 30-frame diameter, with all-angle sleeve bearings and resilient base mounting. It is available in ratings from 1/12 to 1/3 hp.



TYPICAL SPEED-TORQUE CURVES for polyphase, split-phase, and capacitor-start models show that the form G will match the performance of the former motors in all standard ratings and motor types. Good performance is attained even though the use of critical materials is greatly reduced. About 50 percent more horsepower per pound of material is realized.

(when used), and the switch. The form G motor is designed with the switch assembly as a part of the stator shell, so all connections are made independently of the end shield. This eliminates the possibility of broken leads or insulation damage.

The type KC, general purpose motors are single phase and available in ratings from $\frac{1}{6}$ to 1 hp; 3,450 to 950 rpm; 115, 230, 115/230 v; 60, 50, 25 cycles; open (dripproof); 40 C rise; solid or resilient base. The totally enclosed fan-cooled motors of the same model have ratings from $\frac{1}{6}$ to 1 hp; 55 C rise; large size ball bearings; continuous duty; solid base; and are alike in other respects.

The type KH, standard split-phase motors are single phase, and available in ratings from $\frac{1}{12}$ to $\frac{1}{3}$ hp; 3,450 to 950 rpm; 115, 230 v; 60, 50, 25 cycles; 40 C rise; sleeve bearings; open (dripproof). The special-service split-phase motors of this model are available only in $\frac{1}{4}$ and $\frac{1}{3}$ hp ratings, with all-angle sleeve bearings, and for continuous duty.

The type K, general-purpose, polyphase motors have ratings from $\frac{1}{6}$ to 1 hp; 3,450 to 950 rpm; 60/50, 25 cycles; full voltage start; constant speed; sleeve bearings. The totally enclosed fan-cooled motor of this model has ratings from $\frac{1}{6}$ to 1 hp; ball bearings; and continuous duty.

General Electric Co., 1 River Rd., Schenectady 5, N. Y.

CONTINUED ON PAGE 220

Forged Stainless Steel High Pressure Globe Valve

This forged stainless steel globe valve has parts that are machined and welded together to give a full flow through valve. Packing gland bolts are eliminated, and the size and weight of the valve is reduced by 75 percent over cast steel valves.

The valves are polished internally to help prevent corrosion, and are then welded closed. They may be used with poison liquids and gases, and are in the 10,000 lb class. The valves may be furnished with either bolted or welded caps, and screwed flanged or socket weld ends.

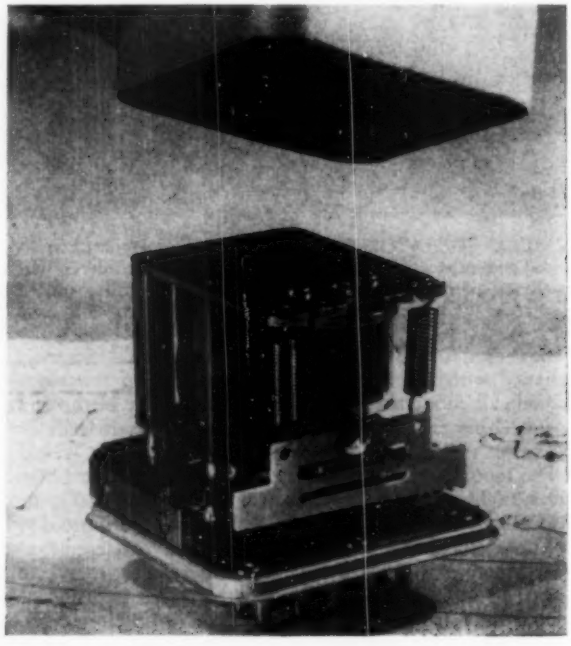
The material used is stainless steel, type 302,304,321, and 347 for the value bodies. Stems and discs are made of a new stainless steel known as #322, which is now available, with the good combination of a high degree of corrosion resistance and uniform hardenability.

The 10,000 lb valve measures 12 in. end to end, and 19 in. from center to top with the valve open. It is said to have four times the tensile strength of the cast steel valves. A 4 in. cast steel valve is said to be more than 26 in. end to end, 48 in. from center to top, and classed at 2,500 lb. The one in. stainless steel valve is 4½ in. end to end, and 5½ in. from center to top with the valve open.

Valves can be furnished from ½ to 6 in. either horizontal or angle. Check valves are of the piston type.

A. F. Hoppe Engineering, Inc., Greensboro, Ind.

Plug-In Type Electric Circuit Controller



A compact, universal, electric-circuit controller with large power handling capacity, is now being made for converting low-power-level signals into control signals of a much higher power level.

The new plug-in unit, known as Regohm size 3, is a control which can be utilized in voltage, current or speed regulation, and can be adapted to important functions in servo systems. Compact design is said to make the new regohm adaptable to rotating machinery, line and load regulation, rectification, battery charging, servo mechanisms, saturable reactors, and close differential relays.

The unit is available in a variety of forms to suit particular applications. It can be built with 20 standard fingers of 1 amp, 12 w capacity, or 10 extra heavy fingers of 3 amp capacity. Fingers may be connected in parallel when control circuit currents are greater than these values. An auxiliary contact is available which makes it possible to design resistance banks with zero minimum resistance.

Like other regohm units, the coil circuit can be operated from signal sources of widely varied voltages and frequencies. A minimum of 1.5 w is required for the coil current which is available in impedances varying from 0.01 to 10,000 ohms. The unit operates directly on d-c or 50 to 60 cycles a-c. The new regohm is 2 in. x 2 in. x 2 in., and can be hermetically sealed.

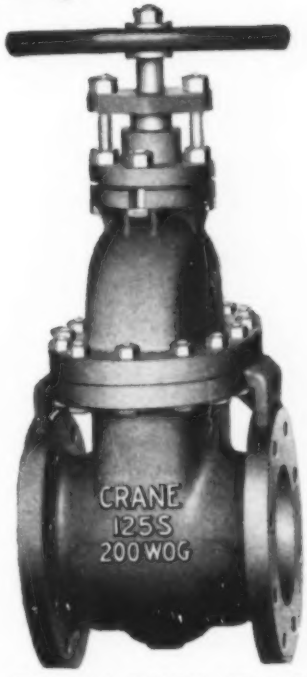
Electric Regulator Corp., South Norwalk, Conn.

CONTINUED ON PAGE 222

To write piping specs faster...
Go right to your CRANE Catalog

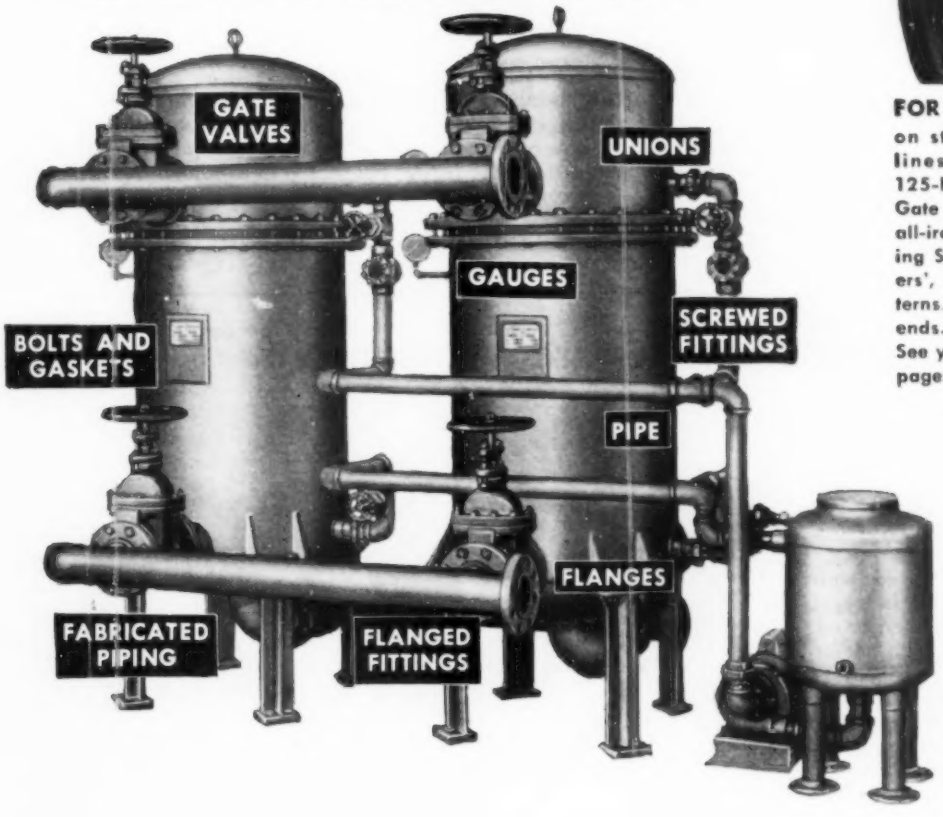
You'll write 'em up faster then—for many reasons. Your Crane Catalog not only contains an unequaled selection of quality piping materials, but also lists every item so you can find it in a hurry... find out all about it, too. Complete breakdown on every valve and fitting includes sizes and dimensions; tabulated pressure and temperature ratings; design, material, and construction details.

In addition, there's an abundance of general engineering data in the Crane Catalog to help you over many hurdles in designing piping systems. And today—when work loads are heavier, replacements harder to get—your product gains added value with customers when it's equipped with dependable, longer lasting Crane Quality piping materials.



FOR ALL-ROUND SERVICE on steam, water, oil, or gas lines... Crane recommends 125-Pound Iron Body Wedge Gate Valves, brass trimmed or all-iron. Available in Non-Rising Stem, O.S. & Y., Underwriters', and Quick Opening patterns. Screwed, flanged, or hub ends. Sizes: 2-inch and larger. See your No. 49 Crane Catalog, pages 77-81.

LOOK TO THE LEADER... CRANE... FOR ALL YOUR PIPING EQUIPMENT NEEDS



Water Feed Filter by R. P. Adams Company, Inc., Buffalo, N. Y.

CRANE CO.

General Offices:
836 S. Michigan Ave., Chicago 5, Ill.
Branches and Wholesalers Serving All Industrial Areas

VALVES • FITTINGS • PIPE • PLUMBING • HEATING

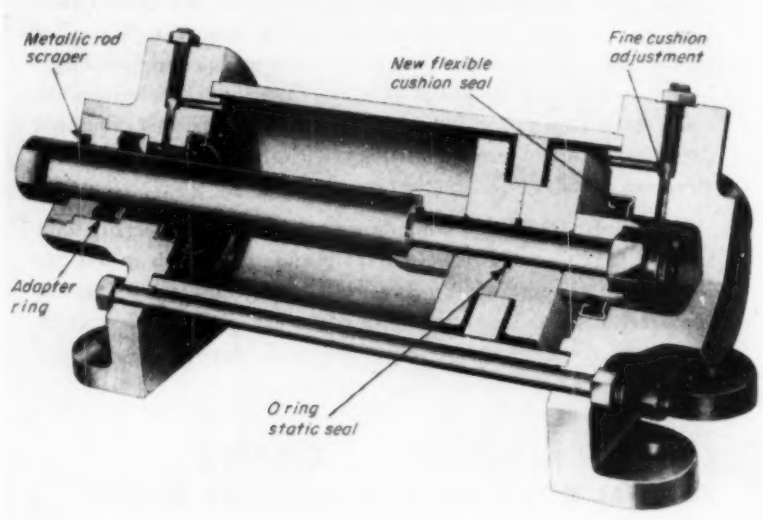
Air Cylinder With Flexible Cushion Sealing

A line of "super cushion" air cylinders, designed with a new type of flexible cushion sealing, gives positive cushion action, combined with automatic valving action for fast return stroke. In addition, it has the advantage of eliminating possible binding and striking which is encountered in other methods where close metal fits are required to make a seal. Although there is almost no wear on the sealing element, it automatically compensates for wear by its "sealing with pressure" characteristics. This new cushion design gives a lower friction factor.

The cylinder also uses a new-type packing nut, incorporating a piloted diameter which will give perfect alignment. The female adaptor feature is an integral part of the packing nut. This packing nut adds rod bearing length, eliminates the necessity of separate female adaptor ring, and cuts down on the stocking of rod packing.

The metallic male adaptor ring, used in the piston rod stuffing box, gives added support to the chevron type packing, which will extend the life of the rod packing.

The metallic rod wiper ring gives protection from dirt and grit. The flexible bronze rings mounted in synthetic rubber wipe off the dirt with their knife-edged conical surfaces. This device is self-adjusting.



Additional features: Hi-tensile tie rod construction; Piston rod and internal cylinder tube surfaces are hard chrome plated. The controlled compression of both piston and rod packings will permit field installations.

Basic design of the cylinder is safety-stressed for air line pressures up to 100 lb psi. The cylinder is available in seven standard styles. Capacities of 100 lb to 12,000 lb, for power movement in any direction.

The Tomkins-Johnson Co., Jackson, Mich.

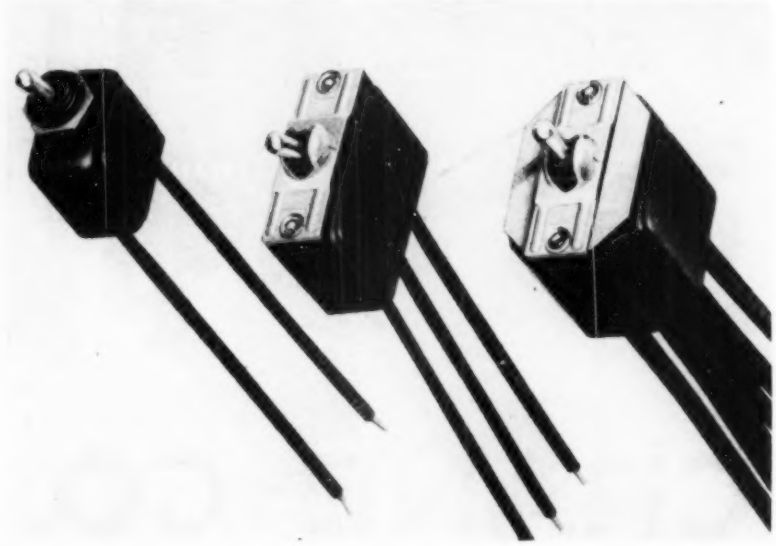
New Toggle Switches are Waterproof

A new series of waterproof toggle switches, developed to meet military specifications, open and close electrical circuits underwater, are said to function perfectly from —65 F to +165 F, and withstand salt spray, shock and vibration.

The switches are furnished with ratings from 20 to 200 amp, in toggle arrangements of momentary on or off and stationary on or off, with one or two hole mounting. Switch body is encased in a molded rubber compound developed and molded by this company. Waterproof lead wires are vulcanized into the rubber case and become integral parts of the assembly, as does the switch mechanism itself.

The switches are suitable for use with power and machine tools, vehicles, farm implements, and appliances.

Riverside Mfg. & Electrical Supply Co., 10228 Michigan Ave., Dearborn, Mich.



CONTINUED ON PAGE 224

IMAGINE MAKING only 10,000 OF THESE

and a profit, too?

RADIO CASE made of Boltaron — the tough, new low-pressure formable sheet.

Any experienced plastics fabricator can do it for you by taking advantage of the low-cost molding methods that Boltaron makes possible.

Formability — Any simple or complex shape can be formed in Boltaron with low-cost molds and molding equipment.

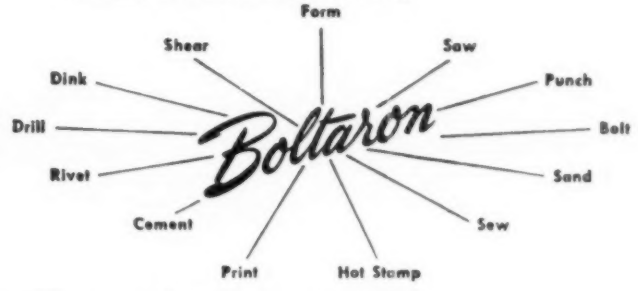
Impact Resistance — Boltaron is unharmed by blows that dent sheet metal, shatter metal castings. Boltaron tote boxes (any shape or size) can be dropped from a second story window . . . last indefinitely.

Other Features — Boltaron can be produced in any color and in several finishes. Colors are an integral part of the Boltaron sheet, won't peel, chip, crack, or scrape off. For further details write for illustrated booklet to

BOLTA, Box 308, Lawrence, Mass.

USES

OFFICE MACHINE HOUSINGS
ADV. & DISPLAY SIGNS
AIRPLANE AND AUTO TRIM
FENDER GUARDS
PACKAGING
TOTE BOXES
LUGGAGE
INSTRUMENT PANELS

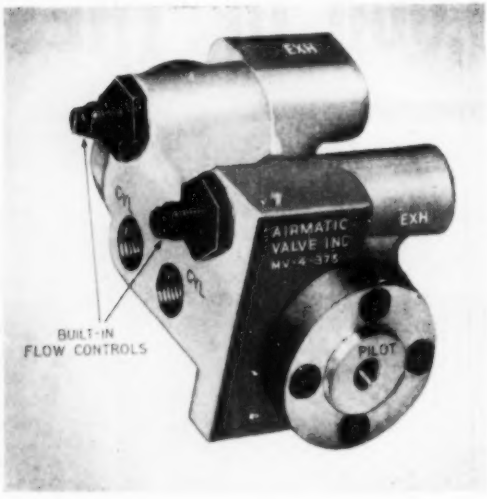


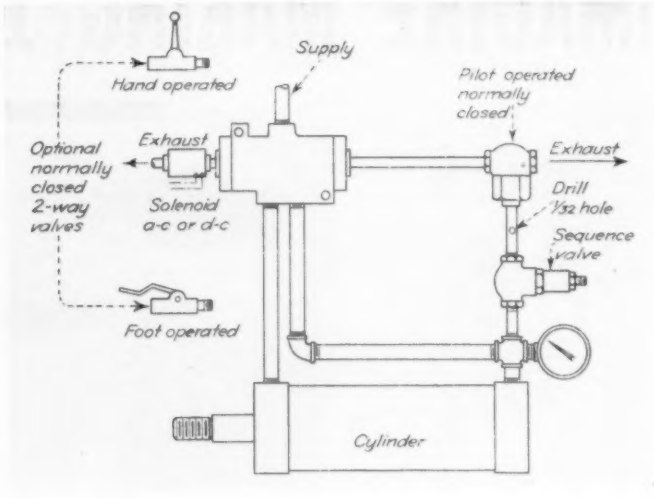
Boltaron

A BOLTA Plastic

NEW! Boltaron 6200, a plastic of remarkable chemical resistance, is available through H. N. Hartwell & Son, 947 Park Square Building, Boston, Massachusetts.

NOTE: Our Custom Molding Division specializes in injection and compression molding of all types. Write direct to Custom Molding Division, BOLTA, Lawrence, Massachusetts.





4-Way Master Valve for Large Bore, Air Cylinders

This new air control valve, model MV-4-375, used with pilot valves to provide automatic and s matic operations, sequence of operations, and control paneling. Said to eliminate insufficient or excessive dwell in air cylinders of 6 in. dia more, the new valve is applicable where larger cylinders are used in certain assembly methods, crimping and staking. Rather than rely on the judgment in controlling the valve for the correc of cylinder pressure, this pilot operated, 4-wa valve is used in conjunction with two auxiliary valves. The momentary operation of either of th valves causes a shift in the valve spool, res movement of the double acting cylinder piston. Th valve causing the piston to advance, is under c the operator and may be operated by hand, foot noid. After the piston has reached the end of i a predetermined amount of pressure builds u

New Alloy W

An alloy is now being produced that is said unusually efficient properties for machining, beari sure die-casting, and heat dissipation. Called C the metal may be used for dry bearings, and for aluminum as a welding rod without flux.

The approximate composition of the alloy is: 8 zinc; 5 percent copper, brass, or bronze; 3 to solder; 3 percent aluminum with one or two deviation. The metals are melted together; then cal mix containing muriatic acid, some smelter other ingredients are used to produce a wet mass which is mixed with the molten metal. In the metal has been broken down into three l sions: the bearing metal contains some lead metal has more aluminum; and the welding rod lightened with more aluminum and chemical treat

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Plug-In Construction on New Calibrator

The features of the model D-2 calibrator, a device for the accurate generation of pulse trains, include: a new mechanical design using plug-in type construction to simplify construction and maintenance; improved ventilation; an added selection of pulses available from the rotary switches; and improved appearance of the front panel.

The model D-2 calibrator has 17 different pulse rates available at the output connections. Coincidence circuits are used to make negligible the phase lags between the various outputs.

Because of the wide range of outputs, together with the low phase lags, the instrument is used for the calibration of synchroscopes, and the time delay generators made by this company. It may also be used as a secondary frequency standard, as a master timing

Some of these are produced
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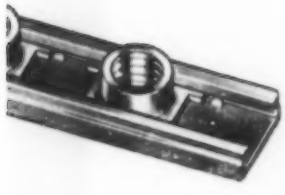
ition period.

Rutherford Electronics Co.,
bertson Blvd., Culver City, Calif.

Channel



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he Kaynar Mfg. Co., Kaylock Div.,
820 E. 16 St., Los Angeles, Calif.

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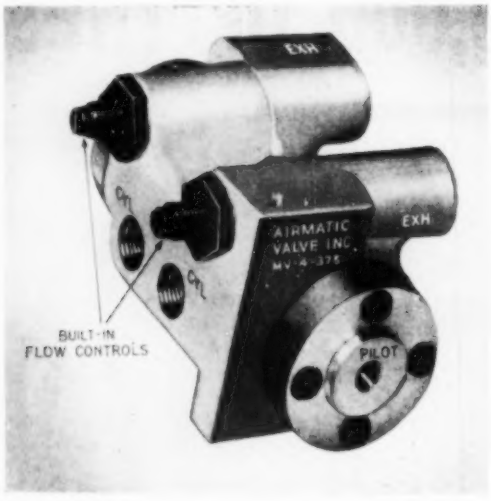
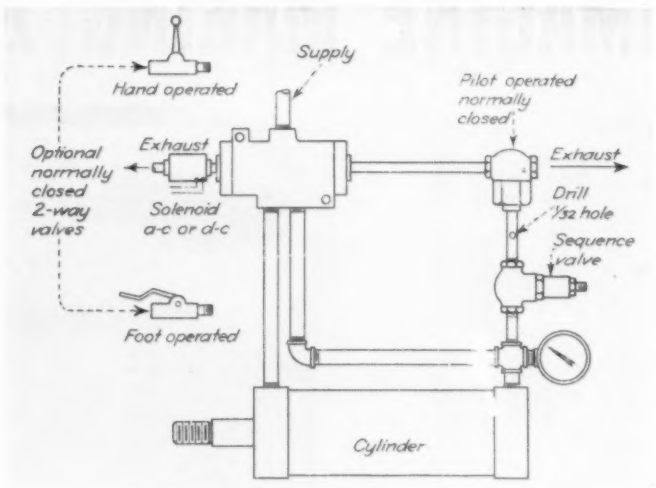




4-Way Master Valve for Large Bore, Air Cylinders

This new air control valve, model MV-4-375, may be used with pilot valves to provide automatic and semi-automatic operations, sequence of operations, and remote control paneling. Said to eliminate insufficient pressure or excessive dwell in air cylinders of 6 in. diameter or more, the new valve is applicable where larger bore air cylinders are used in certain assembly methods, such as crimping and staking. Rather than rely on the operator's judgment in controlling the valve for the correct amount of cylinder pressure, this pilot operated, 4-way master valve is used in conjunction with two auxiliary bleeder valves. The momentary operation of either of the bleeder valves causes a shift in the valve spool, resulting in movement of the double acting cylinder piston. The bleeder valve causing the piston to advance, is under control of the operator and may be operated by hand, foot, or solenoid. After the piston has reached the end of its stroke, a predetermined amount of pressure builds up which opens the sequence valve. Since the sequence valve can be adjusted for the desired pressure, air is admitted to the pilot side of the pilot-operated bleeder valve, thus opening this valve and causing the master valve spool to shift and return the piston to its starting position.

To avoid interference of air pressure for operating the pilot valve, a small hole in the line is used to bleed off the air pressure that would otherwise be trapped when the sequence valve closes at the maximum retraction of the piston. The new 4-way valve is said to have proved reliable and accurate in field installations. With only one moving part, the valve: has a positive, bubble-tight shut-off; is non-corrosive and self-compensating for wear; and is compact. Designed for use with air, oil or water at all pressures from zero to 150 pounds, it is available for use with standard pipe sizes of $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$ and $\frac{3}{4}$ inch.

Airmatic Valve, Inc., 1643 E. 40 St., Cleveland, Ohio

New Alloy With Unusual Properties

An alloy is now being produced that is said to have unusually efficient properties for machining, bearings, pressure die-casting, and heat dissipation. Called Chemalloy, the metal may be used for dry bearings, and for welding aluminum as a welding rod without flux.

The approximate composition of the alloy is: 85 percent zinc; 5 percent copper, brass, or bronze; 3 to 5 percent solder; 3 percent aluminum with one or two percent deviation. The metals are melted together; then a chemical mix containing muriatic acid, some smelter slag and other ingredients are used to produce a wet chemical mass which is mixed with the molten metal. In practice the metal has been broken down into three basic versions: the bearing metal contains some lead; casting metal has more aluminum; and the welding rod has been lightened with more aluminum and chemical treatment.

There is no oil impregnated in the metal when it is used for dry bearings. One drop of oil is used on the bearing at the start before the chemicals work to the surface. Water may be used as the initial lubricant. The heat expansion is less than 1/10 that of steel, or 0.0000265.

It was discovered that the process is effective in decontaminating zinc-based die metals after exposure to lead. After being contaminated by lead, the zinc dies often crack as a result of their impact strength being reduced.

The manufacturers claim that the alloy defies rust, resists corrosion, works without lubricants in moving parts, and remains cool while being lathe-turned.

Other characteristics are: hardness, 60 Rockwell B; tensile strength, 50,000 psi; compression strength, 100,000 psi; begins to liquify at 400 C.

Chemalloy Associates, Santee, Calif.

CONTINUED ON PAGE 227

Plug-In Construction on New Calibrator

The features of the model D-2 calibrator, a device for the accurate generation of pulse trains, include: a new mechanical design using plug-in type construction to simplify construction and maintenance; improved ventilation; an added selection of pulses available from the rotary switches; and improved appearance of the front panel.

The model D-2 calibrator has 17 different pulse rates available at the output connections. Coincidence circuits are used to make negligible the phase lags between the various outputs.

Because of the wide range of outputs, together with the low phase lags, the instrument is used for the calibration of synchroscopes, and the time delay generators made by this company. It may also be used as a secondary frequency standard, as a master timing oscillator for pulse equipment, for the generation of timing signals for oscillographic recording, and the detection of jitter in delayed signals.

Simultaneous outputs having the following pulse spacings are available: 10, 100, 1,000, 10,000, and 100,000 microseconds. In addition, a selection of one of the following pulse spacings is available: 20, 50, 200, 500, 2,000, 5,000, 20,000, 50,000 and 200,000 microseconds. Also, a selection of pulses is available for calibration purposes. Some of these are produced by a single shot multivibrator having a pulse width which is a function of the repetition period.

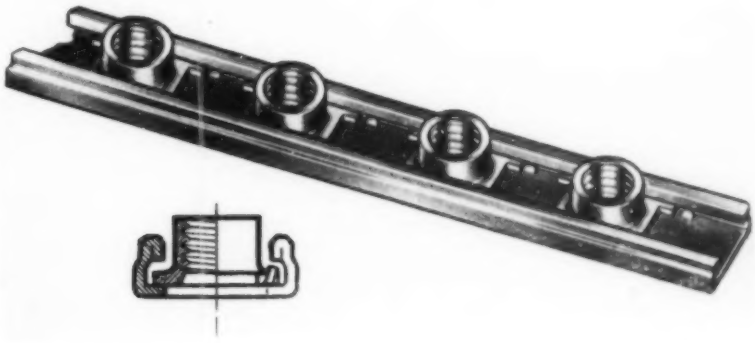
Rutherford Electronics Co., 3707 S. Robertson Blvd., Culver City, Calif.

Small Nut Size, Compact Gang Channel

This multiple lock-nut fastener, called the gang channel, is of such small design as to make its application interchangeable with the standard type of anchor nut. Containing spring steel lightweight locknut inserts, this multiple nut fastener is said to be narrower, lower, lighter, and stronger than any similar product.

Made of 24 Alclad aluminum alloy to Army and Navy Air Force specifications, the channel portion features a double-vertical wall, giving high push-out resistance, plus maximum rigidity, therefore requiring less riveting for attaching. Its small nut size also allows close center to center spacing. The gang channel is as narrow as a standard AN-366 anchor nut, making it possible to install wherever standard anchor nuts were used.

The inserts used are the spring steel high temperature self-locking nuts, made by this company, which have good wearing qualities, and are of light weight material. They are said to be stronger than any bolt, have high locking resilience and are impossible to damage by cross threading. Using all threads for load carrying, they are made elliptical at the upper portion, then heat treated to give a strong flexible threaded portion which grips the bolt within the span of the normally required number of threads, without requiring an auxiliary locking device. Like the self-locking anchor-nut produced by this company, the nuts are not adversely affected by lubricants or solvents.



Made presently in sizes ranging from 8-32 through ¼ in.-28 size, the gang channel is obtainable in either regular hole spacing or to any special hole pattern.

The Kaynar Mfg. Co., Kaylock Div., 820 E. 16 St., Los Angeles, Calif.

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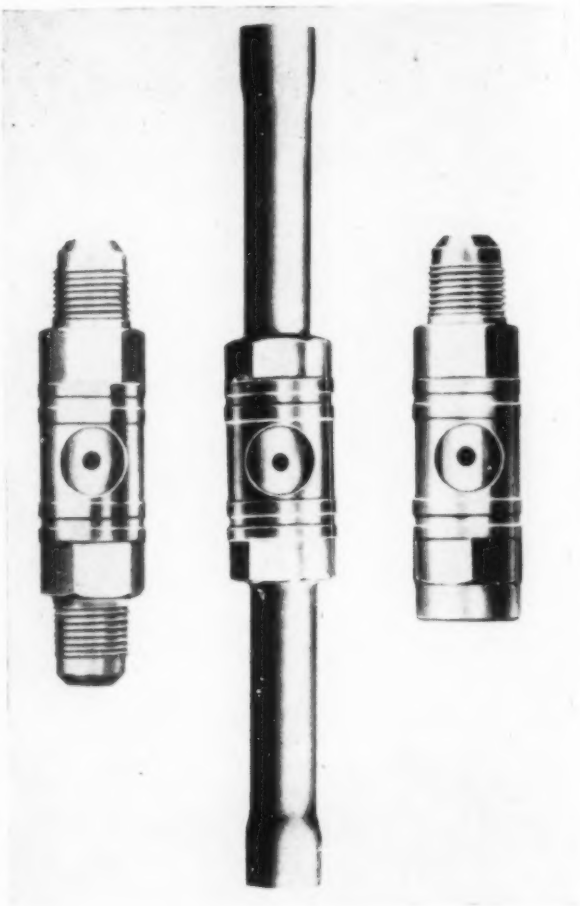
Visual Flow Line Indicator in Small Sizes



A simple, positive flow indicator is now available which is incorporated into the line, and gives instant visual inspection without the necessity of reading pressure gages. Known as the Liquid Eye, this indicator consists of a brass housing in which is inserted a transparent high pressure pyrex tube with a ceramic eye which visually magnifies when the liquid line is full. The straight through design eliminates pressure drop, and construction is such that it is not affected by the most commonly used chemicals, solutions and oils.

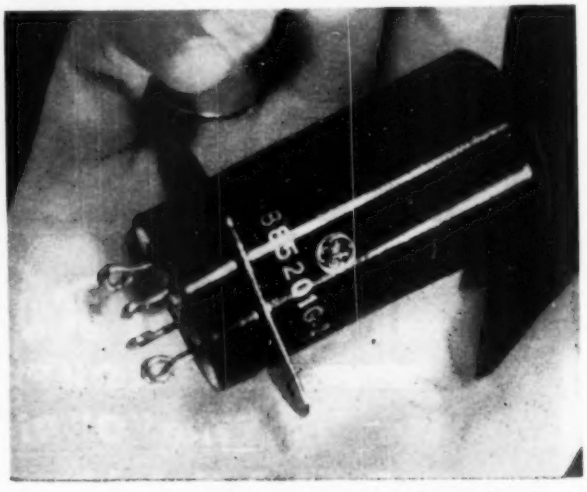
The high quality brass housing and ends are machined to exact tolerance and the high pressure pyrex glass tube is ground and lapped by a special process. The gasket material is impervious to action by liquids that are not affected by brass, and does not decompose or swell.

The liquid eye has been designed with the pyrex glass tube spring mounted for shock resistance, and the method of seating the gasket against the ends of the lapped glass prevents the glass from touching the housing. Assembly is completed with torque wrenches to get absolute uniformity. The indicator is so light in weight that there is practically no fatigue factor in the liquid line. Each indicator is shock pressure tested under conditions which simulate a pressure surge when a valve is opened. Three styles are available in copper tube sizes of $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$ and $\frac{5}{8}$ in. with male flare ends, female to male flare ends with copper flare insert in the female end, or with solder connections.

The indicators have been tested and found practical and satisfactory in boiler feed conditioner lines, in oil pressure lines, diesel fuel oil lines, and refrigerant lines.

Allin Mfg. Co., 1153 W. Grand Ave., Chicago 22, Ill.

Magnetic Convertor Measures Low Level D-c



This small magnetic convertor has been designed for use in converting low-level d-c error signals to a-c voltage in a wide variety of measurements systems. A magnetic-amplifier-type device, weighing only three ounces and encased in the metal envelope of a 6L6 radio tube, it can be used wherever control is required from small d-c signals.

It has been developed primarily for use on 400 cycle power, giving a double-frequency output of 800 cycles. However, it may be used on other frequencies by selecting a suitable value of the external capacitor which tunes the output. Power supply is 400 cycles, 6.3 v a-c in series with a 51 ohm resistor. Signal input is a small d-c voltage usually less than one millivolt, but may be 10 millivolts.

The six terminals shown are used for connecting the leads. Because of its stability, low-temperature-rise, and lack of moving parts, the converter is said to operate continuously and reliably over long periods of time.

Suggested uses for this hermetically sealed unit are: exhaust-gas temperature control of jet engines; control-approach systems; computing devices; industrial measurements; and servo mechanisms and electronic control systems.

General Electric Co., 1 River Rd., Schenectady 5, N. Y.

CONTINUED ON PAGE 232

Reduce the use of critical alloys in gas turbine structures

N-A-X AC9115 ALLOY STEEL offers a means of reducing the use of critical alloy steels of the "stainless" type in gas turbine and similar applications. In specific cases it has replaced over half the amount of strategic material originally required, with no sacrifice of quality.

N-A-X AC9115 ALLOY STEEL has high strength and toughness values at temperatures ranging from −70° F. to +1,000° F. It can be readily cold formed into the most difficult shapes; its response to welding by any process is excellent. It must, however, be suitably coated for protection against cold or hot corrosion.

N-A-X AC9115 ALLOY STEEL is available in bars as well as flat rolled products. Investigate the outstanding properties and characteristics of this steel and, through its use, conserve the critical material so necessary to our nation.

with N-A-X AC9115

ALLOY STEEL

GREAT LAKES STEEL CORPORATION
N-A-X Alloy Division • Ecorse, Detroit 29, Michigan

NATIONAL STEEL CORPORATION

Simplified Radioactivity Survey Instrument

A recently developed radioactivity survey instrument is said to eliminate the expensive and fragile moving pointer microammeter generally used to indicate radioactivity levels. Instead, the level of radiation is read from a calibrated potentiometer dial. The operator, wearing the small earphone shown at the right in the illustration, turns the dial to the point at which an audio oscillation just begins. This indicating method is more convenient than a microammeter for plotting contours of equal radiation. Leaving the dial set, the operator can easily locate a series of equally radioactive points as he walks along.

Like other gamma-radiation survey instruments, the device uses a detector tube of the halogen-filled GM type, together with a vibrator high voltage power supply operating from flashlight type batteries. Output current of the detector is proportional to the incident radiation.

The heart of the aural indication method is a thyratron relaxation oscillator circuit. If the potential difference between the grid and cathode of the thyratron exceeds the firing potential, the circuit will oscillate. The unknown voltage derived from the detector tube current is applied to the outer terminals of the potentiometer, while the thyratron grid is connected to the moving contact. The potentiometer setting at the threshhold of oscillation therefore depends on the radiation level, and the potentiometer dial can be calibrated directly in radiation units.

National Bureau of Standards, Washington 25, D. C.

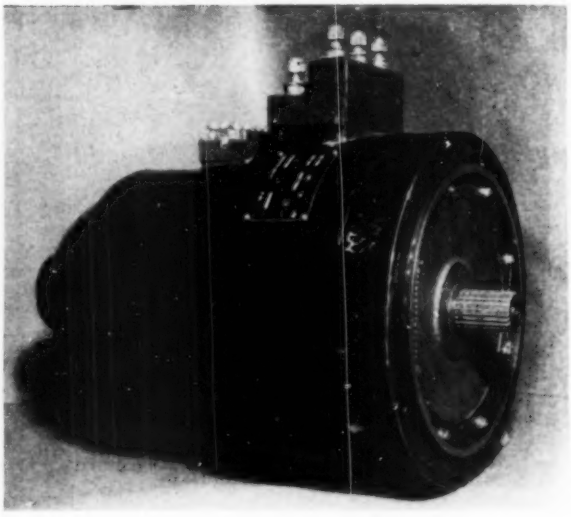
Three-Phase Generators Have Variety of Ratings

A line of 3-phase, a-c generators, especially designed for aircraft, will soon be available in a variety of ratings from 15 to 90 kva at 120/208 volts. The generators have normal operating speeds ranging from 3,800 to 8,000 rpm, and may be either wye or delta connected.

The manufacturers list the following advantages for the new a-c generators:

1. Savings in weight up to 30 percent can be realized when a-c generators are used instead of d-c generators.
2. Three hundred percent short circuit current rating provides a safety margin that insures operation of line clearing devices in event of electrical fault, thus giving good short circuit protection.
3. Nearly perfect sine wave output of the a-c generators will give proper operation of electronic equipment requiring a low percentage of harmonics in the voltage wave form.

The manufacturers claim that the new generators will find power application in new aircraft construction to furnish a-c power for deicing equipment for exterior surfaces of aircraft, for radar and radio, and internal heating.



General Electric Co., Schenectady 5, N. Y.

A SAMPLE CARD known as the Dieflex Selector offers an easy way to select the exact size of tubing or sleeving needed to insulate wires. Leads or wires are slipped into the closest fitting hole on an aluminum gage to determine the correct size. Seven samples of different types, grades, and colors are mounted on the board. Insulation Manufacturers Corp., 565 W. Washington Blvd., Chicago 6, Ill.

TYGORUST, specifically developed for use on rusted steel surfaces can be applied by brushing, spraying, or dipping. It dries hard and can be overcoated in several minutes. It adheres well to rusted steel, damp or dry, and can be used with any type of finish coating, particularly vinyls. U. S. Stoneware Co., Akron 9, Ohio.

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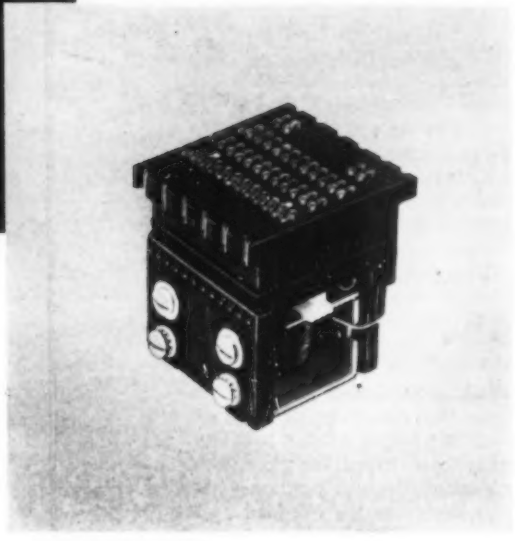
Cream and sugar set, part of a lovely line which has earned the title "The Dresden China of Melmac® Dinnerware"



A tiny, intricate assembly, designed as part of an important product of one of the country's leading manufacturers.

Both are Products of Prolon Plastics!

THE TWO PRODUCTS pictured above indicate what is being done today in fine plastics. The creamer and sugar bowl are part of the Prolon Ware line—23 items in a choice of eight decorator colors, combining the strength and durability of Melmac® dinnerware with the most graceful and attractive designs. The tiny, complicated assembly unit shown above is molded to the most rigid specifications and exact tolerances, under contract to a major manufacturer in the field of business machines.

Services of Prolon Plastics include research, design, engineering, die-making, molding and assembly. Whatever your engineering or manufacturing problem, Prolon will give you the best solution.

Prolon has plants at Florence, Massachusetts, and Toronto, Canada. For free informative booklet illustrating Prolon facilities and services, address:

Prolon Plastics (C) Pro-phy-lac-tic Brush Company

Florence, Massachusetts

Overload Release for Torque-Arm Speed Reducer

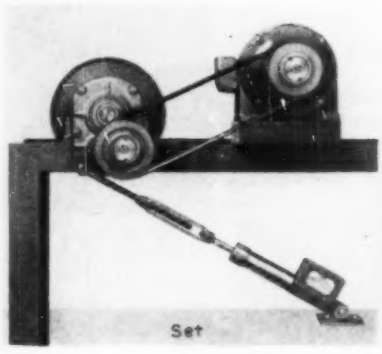
An overload release for the Torque-Arm Speed Reducer, which gives instant and positive protection for driven machines, motors and the speed reducer itself, has been developed to prevent breakdowns, avoid expensive repairs, and insure against interruptions of production resulting from any excessive load on the equipment. The new product has been named the Tri-Matic Overload Release because of the triple protection which it is said to give. The release operates both mechanically and electrically to (1) loosen the belts, (2) cut off the current, and (3) activate a warning bell, siren or light.

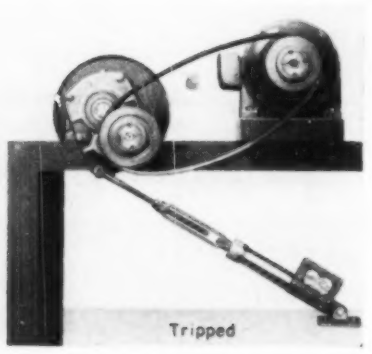
The release acts instantly and positively. Pressure exerted by an excessive load causes a piston to move lengthwise through the unit and this movement loosens the belts and cuts off the current simultaneously. The warning system is hooked up to the micro switch.

The tri-matic is calibrated for adjustment to the load conditions of any Job. To reset the tri-matic after it has been tripped, it is easy to pull the speed reducer back manually into position. This automatically cocks the overload release mechanism.

This new unit replaces the standard torque-arm that is regularly furnished with the speed reducer; the two are interchangeable.

Dodge Mfg. Corp., Mishawaka, Ind.





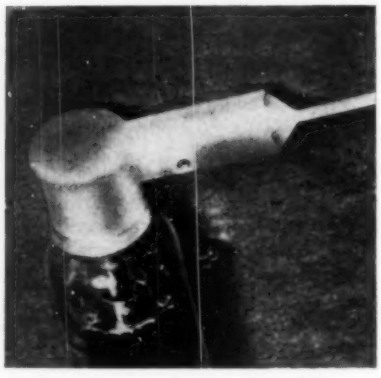
Connector Contains Integrally Molded Resistor

In order to save space, and reduce the weight of cap connectors, a manufacturer has added to his line of high voltage, low-loss tube cap connectors a new design in which a ½ w resistor of any resistance is integrally molded as part of the connector.

Made to fit ¼ in. (miniature) and 23/64 in. (small) diameter tube caps, the 90 ISRI series have the resistor snubbed and spot welded to the grid cap, then to the lead. Using a new method, the grid cap insulation, resistor insulation, and wire insulation is molded into one homogeneous unit giving 100 percent insulation, eliminating danger of arcover or insulation pull back, and providing positive strain relief on lead. The advantages of having the resistor in the circuit pre-built into the cap tube are: (1) space and weight are saved; (2) circuit wiring is simplified; (3) the resistor is protected; (4) solder is saved; (5) and the connections are neat.

By varying the insulating material, polyethylene, polyvinyl, Kel-F (for temperatures up to 300 F continuous operation), this tube cap connector can be widely used for high temperature, high voltage, low loss requirements.

Through the new molding technique: (1) by selecting materials for its high operational characteristics; and (2) by molding the grid cap insulation and lead insulation into one unit to form a positive seal around grid cap and lead, the connectors can be made for many electrical conditions.



Alden Products Co., 117 N. Main St., Brockton, Mass.

CONTINUED ON PAGE 236

Meets Industrial Requirements

- Easily "worked" with ordinary tools
- Takes paints and other finishes easily
- HOLDS applied paints and other finishes
- Hard-smooth-grainless. Will not splinter or crack
- Can be sawed, drilled, punched, die-cut
- Can be curved, bent, shaped
- Structurally strong in all directions; dimensionally stable
- Economical and versatile
- Choice of types, densities, sizes and thicknesses
- Types for interior and exterior uses

HERE is a complete new hardboard line, manufactured under rigid controls, to supply a high quality product meeting strictest requirements of manufacturers, fabricators and other industrial users.

Simpson Allwood Hardboards retain advantages of wood without the disadvantages and weaknesses of wood in its natural state. They are grainless, strong, durable, light-weight, permanent and easy to work with. They are the ideal material for hundreds of uses today, and new uses are constantly being discovered.

To learn how Simpson Allwood Hardboard can help solve *your* problems . . . and perhaps at a saving . . . write us for information and samples, or mail the coupon below.

Simpson

SIMPSON LOGGING COMPANY

Sales Division, 1065 Stuart Building, Seattle 1, Washington

Simpson Allwood Hardboard is manufactured by Oregon Lumber Company, Dee, Oregon

*T. M. Ore. Lbr. Co.

MAIL THIS COUPON

SIMPSON LOGGING COMPANY, Attention Robert T. Miller PE
1065 Stuart Bldg., Seattle 1, Washington

Please send me free sample and literature on Simpson Allwood Hardboard.

I am interested in _____ type and _____ thicknesses for use in the manufacture of _____

Firm name _____

Address _____

City _____ *Zone* _____ *State* _____

Attention of _____

Electrical Inertialess Weighing System

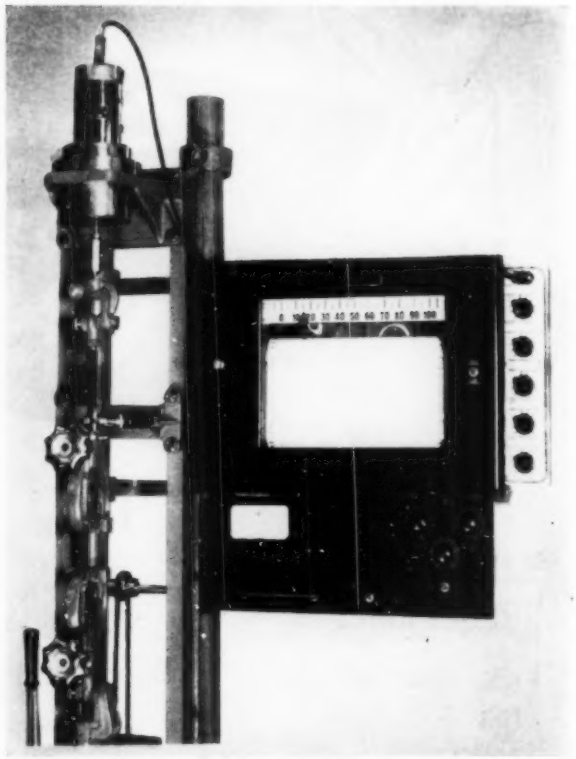
A new electrical weighing system has been designed for application to existing testers of the pendulum type made by his company. This inertialess weighing system replaces the conventional pendulum type head and recorder, converting the tester from constant-speed-of-pull operation to constant-rate-of-extension.

Resistance of the specimen, or load, is absorbed by the deflection of an elastic spool, which is converted to a voltage and measured by a potentiometer with recording chart. On the chart, extension of the specimen is shown vertically and load horizontally, making the chart a stress-strain diagram, with either variable (load or extension) magnified or condensed as desired.

The advantages of the inertialess system are: The inertia is practically eliminated from the weighing mechanism; it is possible to apply a constant rate of extension as the elastic spool of the weighing head elongates only 0.0015 in. maximum; the flexibility of drive and recorder rates, and wide range of chart speeds available, permits new studies of progressive test stages.

In operation, the specimen is inserted in the tester clamps, and the chart pointer adjusted to zero for the existing tare load. The driving mechanism is then set in motion, extending the specimen by moving the lower clamp downward at a uniform predetermined rate of speed. At the same time, by synchronized automatic action, the chart paper commences its downward travel at its predetermined speed. For literal stretch recording, the speed of travel of the chart can be equalized with the speed of travel of the moving clamp. Travel speeds of 0.1 in. to 20 in. per min are available.

As the specimen is extended, the elastic spool in the head weighs the load by its deflection. This deflection is reflected in the horizontal scale, graduated from 0 to 100, as shown in the illustration. The maximum deflection of the elastic member under maximum lb load plus tare is only 0.0015 in., so that this has no practical effect on the recorded extension of the specimen. The accuracy of the system is said to be ¼ of one percent of the span, or better.



Conversions are available from 2 to 10 lb to 400 to 2,000 pounds. The change from one capacity to another is made by changing the elastic member rather than the entire head. This can be done by non-mechanical personnel without special tools.

Scott Testers Inc., 1119 Blackstone St., Providence, R. I.

High Voltage Mercury Thyratron Tube

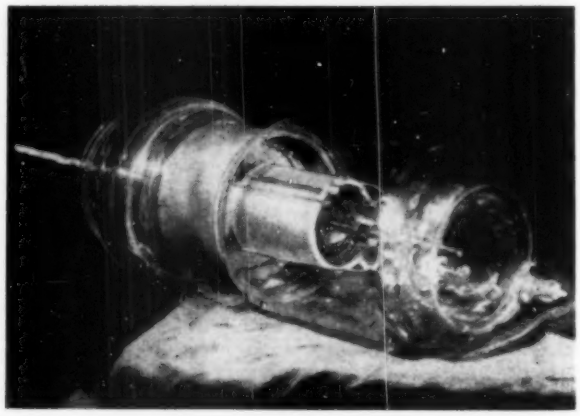
A newly developed mercury thyratron tube capable of handling high d-c voltages and current, has a peak anode voltage of 15,000 v forward or 15,000 v inverse. The tube is a grid control or cut-off or trigger tube.

This mercury filled tube, known as the MT-1530, is said to be able to operate under load conditions that would cause mechanical switches to break down. It has a completely shielded cathode structure, and has a grid at the base of the upper half of the mercury filled tube.

The tube will withstand vibrations normally encountered in industrial use, and may be moved without fear of damage. It carries a 1,000 hour guarantee.

Filament voltage is 5 v, and the current is 30 amperes. Maximum plate current is 100 amps, with 15 amps being average. Maximum surge for 0.1 sec. is 1,500 amps. Condensed mercury temperature limits from 25 to 40 C.

Sheldon Electric Co., Inc., 76 Colt St., Irvington, N. Y.



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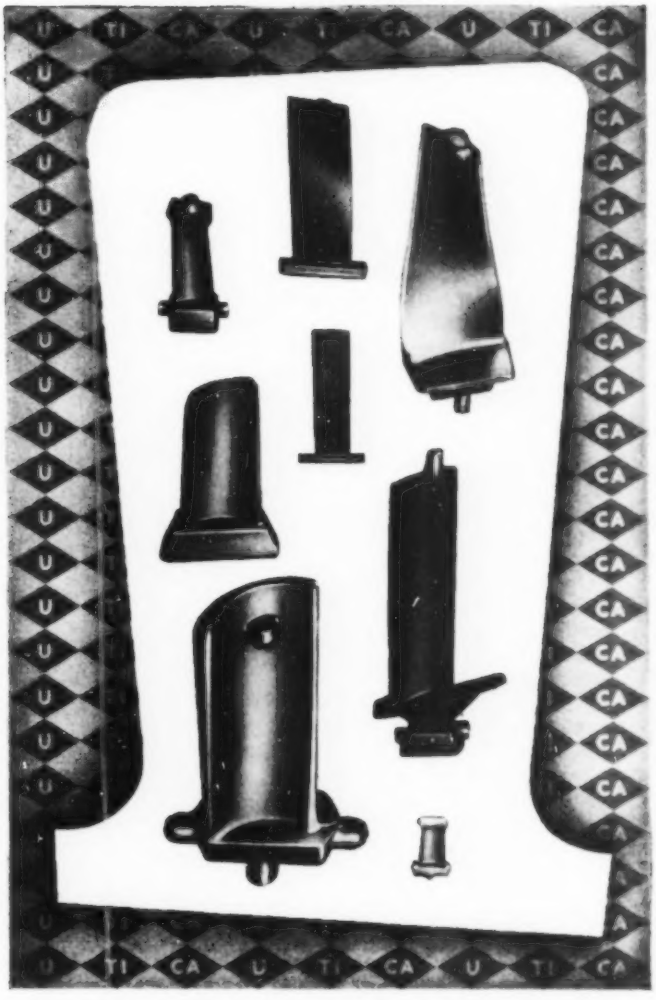


The name, UTICA, famous for quality forged tools for more than 50 years, now identifies a foremost supplier of turbine and compressor blades to the aircraft engine industry.

UTICA HELPS

BY MAKING TODAY'S METHODS "OLD FASHIONED"

...there is no horizon on new ideas at UTICA

In the forging of turbine and compressor blades UTICA is using the most modern methods, the finest equipment and the skill born of long experience in forging.

But, the constant search for improvements goes on. Our engineers and metallurgists work and plan continually to make today's methods obsolete.

So, whether you come into contact with UTICA tomorrow or several years from now, you'll find leadership that reflects this constant hunger for progress. UTICA seeks to help most by working most for advancement.

UTICA DROP FORGE & TOOL CORPORATION, Utica 4, New York

Telemetering Equipment With Fast Response

The telemetering system using the Freq-O-Tron IT-1 transmitter and the IR-1 receiver offers a compact means of telemetering any quantity that can be converted to a proportional d-c millivolt equivalent. It is a frequency type electronic system with instantaneous response. The system may be used for any desired distance over any suitable telegraphic channel, whether pilot wire, power line carrier or radio.

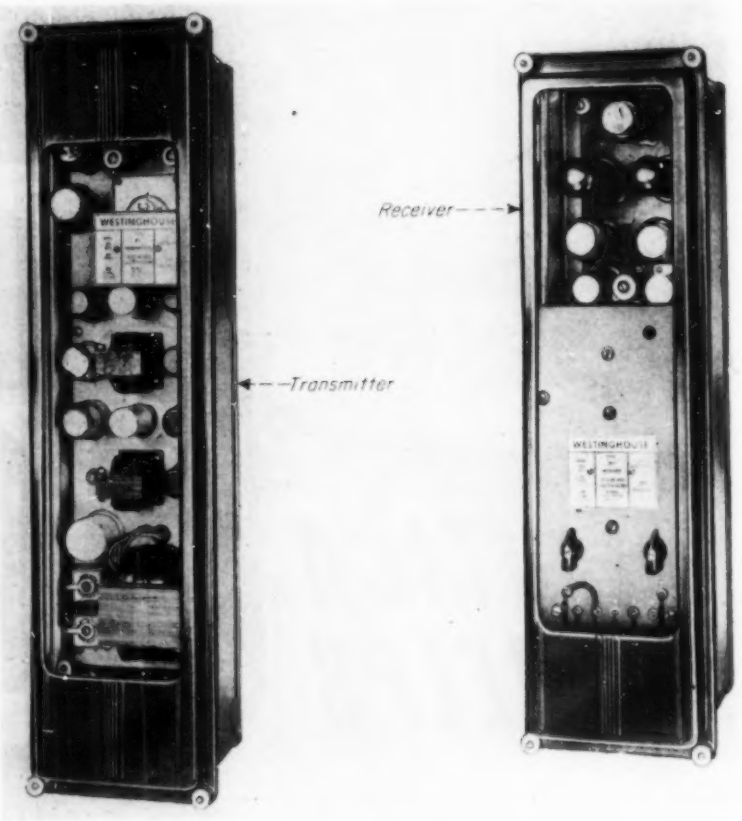
Any number of similar quantities can be totalized, whether at the measuring station, intermediate stations, or the receiving station. The totalized quantity can be retransmitted without using other converting equipment.

Operating time of the telemetering equipment exclusive of end devices, is less than 0.3 second. Overall time including end devices is usually under 3 seconds.

The devices are self-contained in switchboard type cases. They have built-in test switches and do not require external amplifiers or converters.

The telemetering system consists of 5 steps: (1) primary measurement; (2) conversion from millivolts to frequency; (3) transmission; (4) conversion from frequency to millivolts; (5) indication or recording.

Westinghouse Electric Corp., Box 2099, Pittsburgh 30, Pa.

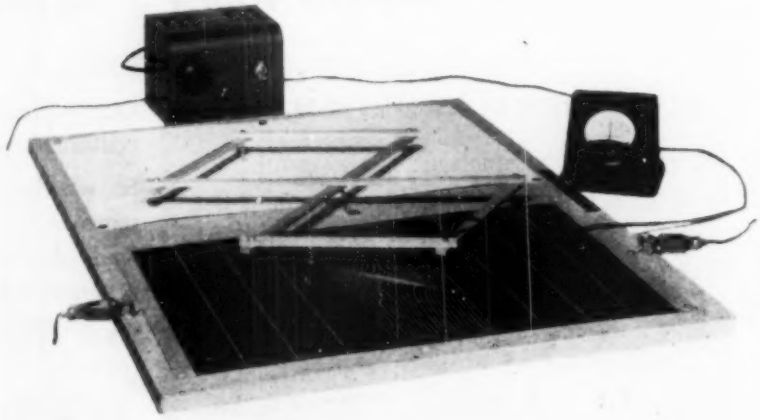


Analog Field Plotter for Complex Problems

This portable analog field plotter, a device used for the rapid solution of complex two dimensional field problems, sets up electrical field patterns in a thin conducting-paper surface on the plotting board. Analogy between the electrical field in the paper and the related field problems, such as might exist in electrostatics, electromagnetics, and thermal and fluid flow, is said to permit easy solution to a broad range of difficult problems.

It consists basically of a plotting board and exploratory stylus, d-c power supply operated from 115 v a-c, a high accuracy multi-turn voltage divider, a sensitive microammeter with specially designed overload protection, and an ample supply of conducting paper and silver paint.

The plotter may be used to study air-flow patterns around shapes in wing and propeller design, and fluid-flow patterns and velocity gradients in steam and gas turbine assemblies.



General Electric Co., 1 River Rd., Schenectady 5, N. Y.

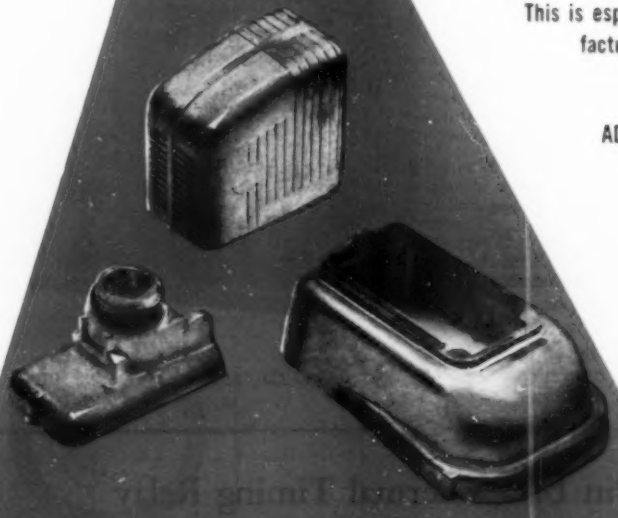
CONTINUED ON PAGE 240

CAST INTO THE FUTURE

In choosing die castings – for civilian or D. O. production – leading manufacturers select ADVANCE PRESSURE CASTINGS. This choice is influenced by a reputation for top-notch facilities, a skilled staff of metallurgists, engineers and technicians operating at every level from blueprint to finished castings, and, above all, unvarying standards of quality and service.

No matter how involved the casting problem, how intricate the design or how demanding the specifications, ADVANCE produces the right castings at the right price. This is especially important today, when many manufacturers are tooling for current defense work or future civilian production.

ADVANCE Development Engineers will gladly consult with you on cost economies and advise you on structural design, alloy specifications and finishing problems of your die castings. Call upon them today without obligation.



ADVANCE PRESSURE CASTINGS Inc

28-30 Wythe Ave., Brooklyn 11, N. Y.

Sales offices:
718 Ellicott Square Building
Buffalo 3, New York

15224 Mack Avenue
Detroit 24, Michigan

2406 South Seventh Blvd.
St. Louis 4, Missouri

Commerce Station Box 71
Minneapolis 15, Minnesota

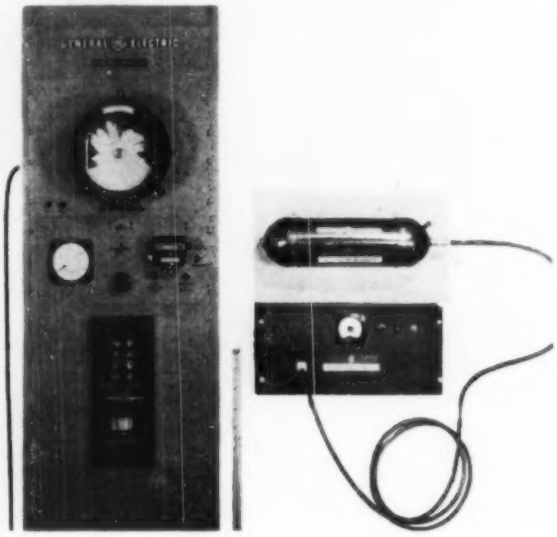
Instrument Monitors Area Gamma Radiations

Called an area health monitor, this instrument detects and records dangerous gamma radiations in an area, and sounds an alarm when average tolerance limits are exceeded. The device gives instantaneous indication of radiation, total radiation received in any preset period, and a thirty-day integrated record of the radiation present in the immediate vicinity of the detector in fifteen-minute intervals. It also contains a means of telemetering the rate of radiation to remotely located indicating stations.

In operation, the area health monitor measures and records the gamma or X-ray's ionizing potential, which is the important factor in determining the effect that radiation will have on human tissue. According to the manufacturers, it is designed as an addition to the present safety and civilian-defense equipment installed in laboratories, atomic-energy plants, hospitals, water works, and areas requiring records of X-ray or gamma radiations.

The standard equipment consists of an air wall ionization chamber, a d-c amplifier, and a six-foot instrument panel that incorporates a torque-balance converter, a watt-hour-meter mechanism, a rate indicator, a cyclometer counter, and a recording device.

Its range is ½ to 5 times tolerance (tolerance is 6.25 milliroentgens per hr), with plus or minus accuracy of 10 percent. Power supply is of 60 cycles, 155 volts.



General Electric Co., 1 River Rd., Schenectady 5, N. Y.

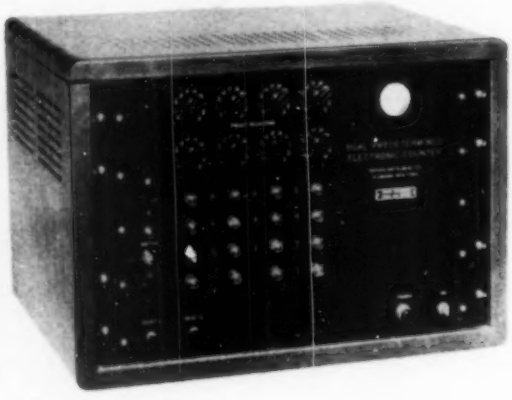
Counter Predetermines Two Different Counts

For applications where the rate of material flow is rapid, the predetermined electronic counter has wide use. The dual predetermining feature makes possible the slowing down in the final stage of a cycle to obtain satisfactory operation of gates, shears, and other devices.

When the count of parts on a high speed conveyor belt approaches the selected batch total, belt speed is reduced by the electronic counter to permit actuation of a gate as the final part is counted. Also, in processing continuous strip material, the counter measures length in terms of drive shaft revolutions, and provides relay control over the roller drives.

The model 243 dual predetermined counter will continuously recycle, accepting counts up to 1,000 per sec, and reset after each output operation without missing a count. The output relay action may be either momentary, adjustable from 0.01 to 0.1 sec, or SPDT stay-put, alternating positions as each predetermined count is reached.

Any two numbers from 1 to 9,999 may be chosen as the counting points at which control actuation is to occur.



Potter Instrument Co., 115 Cutter Mill Rd., Great Neck, N. Y.

Miniature 7-Pin Base Thermal Timing Relay

A sealed-in-glass miniature thermal relay, Model 207, is hermetically sealed in a T-5½ glass envelope with a miniature button 7 pin base, and is designed especially to economize on space and weight. Weight is ½ oz; seated height 2¼ in., dia ¾ inch. Delay periods from 5 sec to 120 sec; standard heater voltages 6.3 v, 27.5 v, and 115 v a-c or d-c. Contacts rated at 2.5 amps, 125 v a-c, or 1.0 amp, 125 v d-c. Ambient compensated from —60 to +85 C. Used as cathode protection in electronic tubes, gyro erection in autopilots, over-voltage and over-current protection, and holdovers and integration.

Thomas A. Edison, Inc., Instrument Div., West Orange, N. J.

CONTINUED ON PAGE 242

Bond Testing of Bi-Metallic Bearing Materials-1

THE nature of bi-metallic bearings requires close control over every step in the manufacturing process. This is not only to insure uniform quality and precision of the finished product, but, what is equally important, to insure the quality of the *bond* between the metals.

* * * *

In many bearing applications, it is desirable to combine the properties of two or more metals or alloys in order to produce a material possessing qualities not obtainable in a single metal or alloy.

The most common of these materials in use today are:

1. Lead or Tin alloys (Babbitts) on a steel back.
2. Lead or Tin alloys (Babbitts) on a bronze back.
3. Bearing bronzes on a steel back.
4. Lead or Tin alloy overlays on a bronze intermediate layer and a steel back.

In the first three cases, the soft bearing surfaces are backed up with the strength of the steel or bronze backing. In the other, the bronze layer affords some protection to the shafting in case of a failure of the overlay bearing surface, while the steel provides strength.

In all cases, their value as a satisfactory bearing material is based entirely on the strength of the inter-metallic or metallurgical bond that can be obtained between the layers. The presence and quality of this bond is assured only by constant testing and checking throughout the manufacturing process, and bond testing has become the subject of major research by the bearing manufacturers.

The ideal bond test would be quick, non-destructive and positive, however these qualifications are not met by any test yet devised. X-ray and supersonic methods have been developed which are quick and non-destructive, but unfortunately, they have not proven to be positive. Large voids can be detected by these means, but very brittle bond, weak bond, or even a complete lack of bond with intimate physical contact, will pass these tests.

Thus, the only completely positive tests available so far are of a destructive nature. Figure I illustrates two destructive tests which are used and which are quite positive—however, the amount of machining necessary for specimen preparation makes them quite slow. The most widely used test is the so-called chisel test which is quick, positive, but destructive.

Off hand this appears to be a very crude method of testing but it has been proven that, with care, accurate interpretations of the results can be made and bond quality can be kept under close control.

Figure II illustrates the chisel test in operation. The chisel is well sharpened, grinding it at an angle of approximately 10-20 degrees, and then hammered down into the material till the bond area is reached. Holding the chisel at an angle of 20-30 degrees, it is driven along the bond line. Examination of the area after chiselling will indicate the quality of the bond, strength of the bond layer and nature of the bond.

Table I lists the general types of bonding encountered with lead and tin alloys on steel and bronze backs.

TABLE I

Material	*Type of Bond*
Lead Alloy/Steel	Ductile
Tin Alloy/Steel	Brittle
Lead Alloy/Bronze	Ductile
Tin Alloy/Bronze	Brittle

The ductility of the lead alloy bond on steel and bronze is due to the fact that the alloy layer formed during the bonding process is ductile. Tin, on the other hand, forms a very brittle compound when it is alloyed with iron or copper in the bonding process. These compounds are very hard and strong in tension, but are very weak in shear strength. Thus, when a chisel is run parallel to the bond line it exerts shear force and will tend to fracture the bond through the brittle alloy layer. The lining metal curls and fractures before the chisel in a pattern which is distinctive for each type bond. From an interpretation of the tests, a semi-quantitative evaluation of the results can be obtained.

The use and interpretation of the chisel method of testing will be more fully described in the second part of this subject.

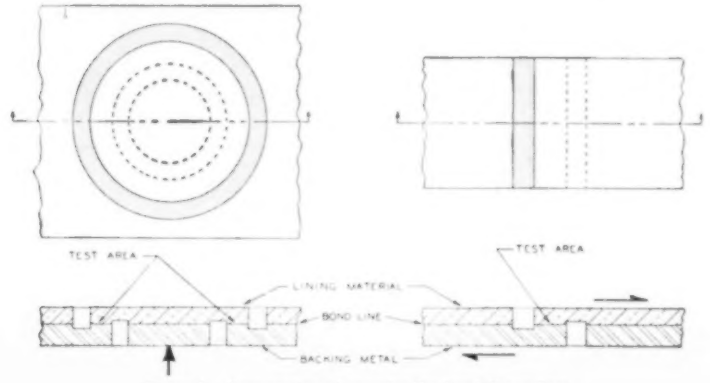


Figure I — Preparation of samples for Bond Shear Test

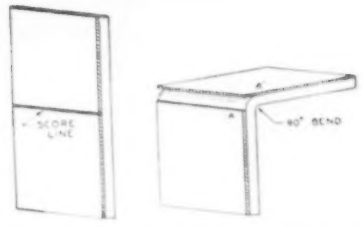
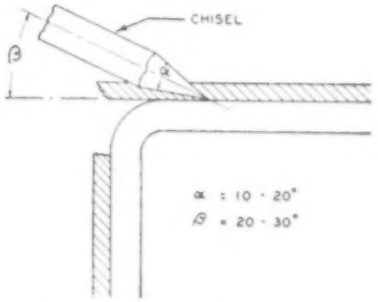


Figure II — Preparation of samples for Chisel Test



Engineering Service

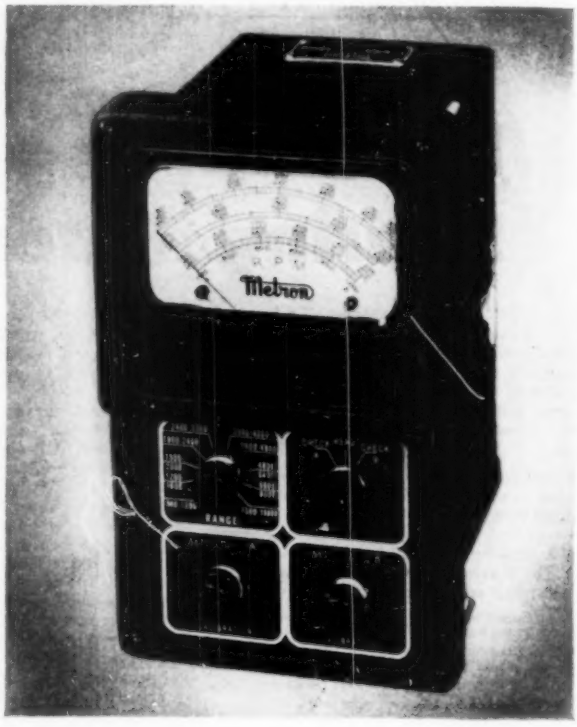
Johnson Bronze offers manufacturers of all types of equipment a complete engineering and metallurgical service. We can help you determine the exact type of bearing that will give you the greatest amount of service for the longest period of time. We can show you how to design your bearings so that they can be produced in the most economical manner. As we manufacture all types of Sleeve Bearings, we base all of our recommendations on facts free from prejudice. Why not take full advantage of this free service?

This bearing data sheet is but one of a series. You can get the complete set by writing to—

Johnson Bronze

SLEEVE BEARING HEADQUARTERS
508 S. MILL ST. • NEW CASTLE, PENNA.

Accurate, High Speed, Ten-Range Tachometers



Having a guaranteed high accuracy of ¼ percent of any speed being measured, this tachometer is well suited for turbine overspeed tests, production motor test stands, dynamometer test stands, laboratories, and other precision speed measuring applications. Accuracy is maintained by use of the calibration adjustment mounted on the instrument.

Ten overlapping and adjoining ranges, which are selected by rotary switch, give more than a 10 to 1 spread in speed. The indicating meter has three scales selected for good readability of minor divisions in integral numbers. Speeds of 36 to 100,000 rpm are covered by three models.

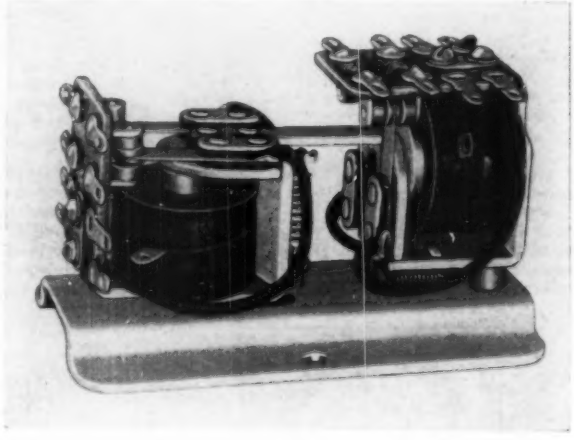
Almost unlimited life and trouble free service is said to be assured by the use of precision parts. No vacuum tubes or other limited life components are used, and the one moving part in the indicator is the pointer, suspended in jeweled pivots. No damage results from selection of the wrong range or by overspeeding.

The fixed installation indicator is suitable for panel or bracket mounting. The indicating meter is mounted in sponge rubber.

Hand engagement or fixed installation heads for a variety of speed engaging applications are available.

Metron Instrument Co., 432 Lincoln St., Denver 9, Colorado

New Small Size Latching Relay



Available in both open and hermetically sealed types, a new series of latching relays, featuring smaller size, higher contact capacity and high vibration resistance, is now in production.

Called the LK series, the new relays are available with contacts up to DPDT on the latching relay and DPDT on the release relay. Therefore, any specified contact combination up to 4 PDT (4 form C) can be obtained. A minimum of 35 grams contact pressure gives positive make or break under vibration forces of 10 G or higher. Relay contacts are ⅛ in. fine silver plated at 5 amp or can be supplied on special order with 3/16 in. silver cadmium oxide, rated at 10 amperes.

The open type LK relay measures 2-15/16 in. long, 1-13/16 in. wide and 1⅜ in. high. The hermetically sealed relay is 3-1/16 in. long, 1-3/16 in. wide and 2-3/16 in. high and is fitted with an all-glass solder terminal header.

Potter & Brumfield, Princeton, Ind.

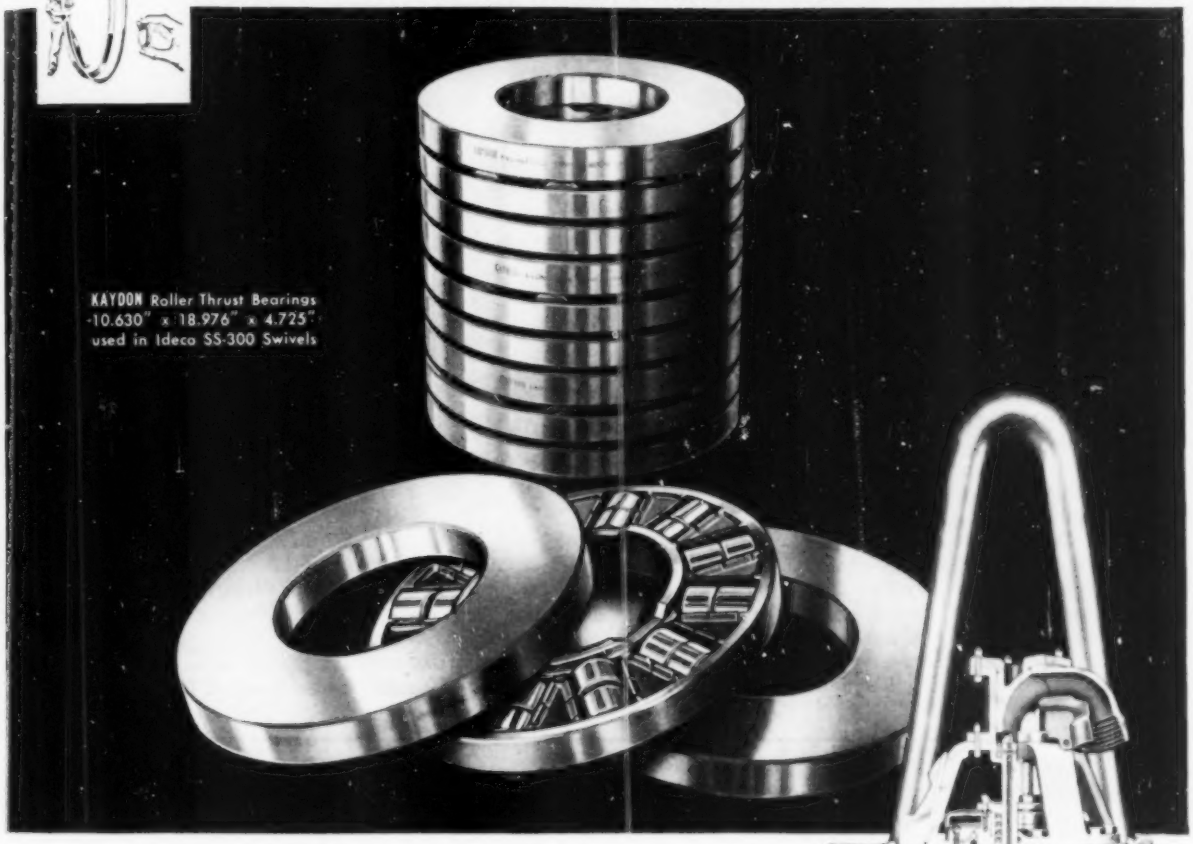
INDUSTRIAL MECHANICAL FREEZERS are capable of producing and holding round-the-clock temperatures of as low as minus 165 F. Models are available with cold chamber capacities from 4 to 45 cu ft, and can give temperatures of —40 F, —80 F, —100 F, —125 F, —150 F, and —165 F. Webber Appliance Co., Inc., 2740 Madison Ave., Indianapolis 3, Ind.

TWO BASIC CLASSES of electrical connectors for equipment and control circuits are being produced. The types are: AN, primarily for aircraft; and O, for ordnance vehicles. Both are available with from 1 to 46, or more, contacts. They are designed to withstand extremes of operation. General Electric Co., Monowatt Dept., 95 Hathaway St., Providence 7, R. I.

CONTINUED ON PAGE 244

Contact KAYDON Muskegon

FOR ALL TYPES OF BALL AND ROLLER BEARINGS: 4" BORE TO 120" OUTSIDE DIAMETER



KAYDON Roller Thrust Bearings -10.630" x 18.976" x 4.725" used in Ideco SS-300 Swivels

Takes 300-ton loads!

Dead-load capacities to 300 tons have been obtained, without added weight, in IDECO Streamlined Swivels for deep oil-well drilling. The success of these rotary swivels is the result of advanced engineering and years of experience in swivel manufacture. Rugged bearings are vital . . . husky KAYDON heavy-duty roller thrust bearings carry the full load.

In many other industries, machine designers find KAYDON bearings help make bigger machines possible, without unnecessary bulk and weight. If you have a bearing problem, contact KAYDON of Muskegon.

IDECO oil-well drilling Rotary Swivel made by IDECO Division, Dresser Equipment Company, (one of the Dresser Industries), Dallas, Texas, showing bearing location.

THE KAYDON ENGINEERING CORP.

KAYDON Types of Standard and Special Bearings:
Spherical Roller • Taper Roller • Ball Radial • Ball Thrust
• Roller Radial • Roller Thrust • Bi-Angular Bearings

MUSKEGON • MICHIGAN

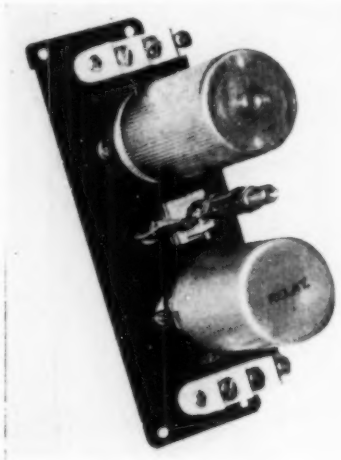
PRECISION BALL AND ROLLER BEARINGS

Under Frequency and Overspeed Controls

The electrical systems of modern military aircraft, and the portable engine-driven generating sets are of the 400 cycle type. Should the frequency of the alternator drop to 360 cycles there would be a high current inrush to the electronic and other electrical loads. This under-frequency control is designed to trip the circuit breaker if the frequency drops below 360 cycles and to close the circuit breaker when the frequency is restored to 400 cycles.

The control does not use electronic components and has the following advantages: high strength; light weight (16 oz); long life; does not require A, B and C power supply.

An overspeed safety control for internal combustion engines and turbos has also been developed, using the same basic principle. This control takes the speed reference either from the ignition system of the engine or the tachometer generator of the turbo. It replaces mechanical overspeed governors to shut off the fuel and/or ignition, should overspeed occur.



It can be arranged for manual or automatic reset and does not require rotating shafts, lubrication or field adjustments. It operates only when overspeed occurs and control is effected electrically.

Shown in the illustration is the model UFR-120-400 under frequency relay with the cover removed, and the overspeed governor.

Electroquipt Controls, Inc., 30 Sagamore Hill Dr., Port Washington, N. Y.

Receiver Device Prevents Mercury Loss

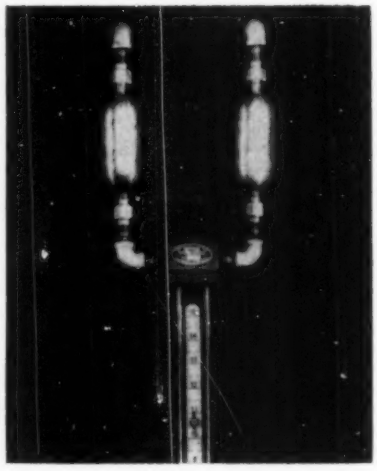
The Mercureceiver, which is designed to trap mercury blown from manometers and achieve equilibrium readings in 10 sec or less, also dampens surges and pulsations, filters, and prevents loss of mercury.

The mercureceiver, is a molybdenum or stainless steel container with threaded end fittings and porous stainless steel membranes. The container capacity of 110 cc for molybdenum steel and 125 cc for stainless steel is more than enough for all the mercury normally present in manometer tubes. Flow capacity of the membranes is adjusted to control mercury at a rate that is proportional to the pressure differential across the porous element.

The mercureceiver is equipped with a porosity HX membrane capable of preventing passage of mercury from the manometer at pressures under 17 psi. Finer porosities are available for use at higher pressures.

When mercury is present in the container, the manometer will not return to 0, thus preventing incorrect readings. Mercury may be removed from the mercureceiver by draining, or by blowing back with an application of more than 25 psi pressure. The upstream side of the mercureceiver is fitted with a porosity E membrane. Mercureceivers are used at both ends of differential manometers and at the open end of absolute manometers.

Chemiquip Co., 6 East 97 St., New York 29, New York



NEW GEIGER MUELLER counter tubes, known as the model B1E, are now available with $1\frac{1}{8}$ in. dia windows, and in any thickness from 1.6 mg/cm² or up, for users of radioactive isotopes. Features of the new tube are: small overall size; and unique metal construction. Primarily intended for precise measurements in the modern radioactive assay laboratory, the ruggedness and the short resolving time of these counters also make them suitable for field operations at any altitude in the measurement of strong as well as weak radiation sources. Advanced design is said to give good electrical specifications. Nuclear Development Lab., P. O. Box 7034, Kansas City, Mo.

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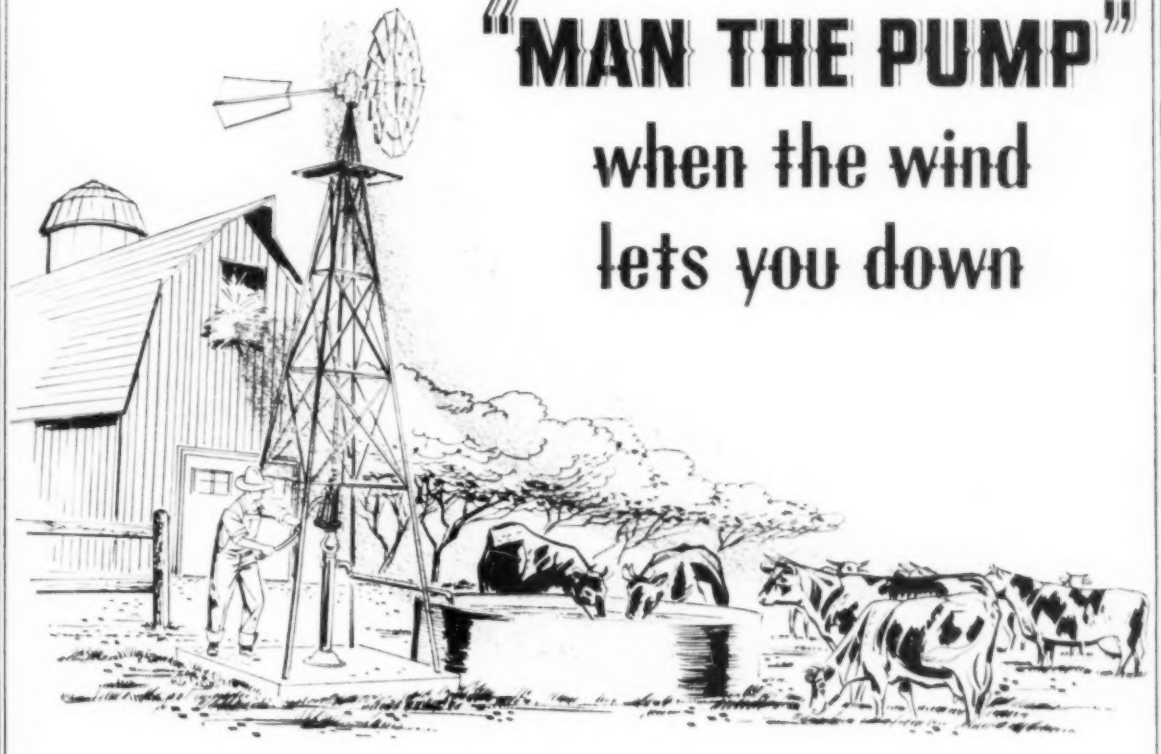
"MAN THE PUMP" when the wind lets you down

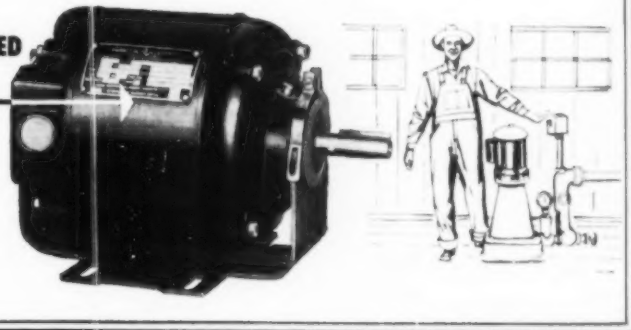


When air currents abate, the farmer must supply the energy, unless there is a motor to take his place. At the mere flip of a switch, this time-consuming task can be eliminated.

It was during the 1890's that Emerson Electric was founded . . . a company which has since become a leader in producing motors which have taken over so many farm chores. Today electric power has nearly 200 farm applications. The hired hand has truly been replaced by the "wired hand."

Emerson-Electric has earned an enviable reputation for dependability and efficiency in its motors on the farm, in the home, in business and industry. Your inquiry is invited on this complete line, in horsepower ratings from 1/20 to 5. THE EMERSON ELECTRIC MFG. CO., St. Louis 21, Mo.

MODERN FARMING IS POWERED WITH ELECTRIC MOTORS



HERMETIC MOTORS
⅛ to 10 H. P.

Emerson-Electric offers manufacturersof hermetically sealed units a broad background of engineering experience, covering all phases of hermetic motor design, specification and performance. In addition, unequaled, specialized facilities are available for the production of hermetic motor parts. Cooperative engineering service is available without charge. Write us today for Free bulletin No. M106

EMERSON ELECTRIC
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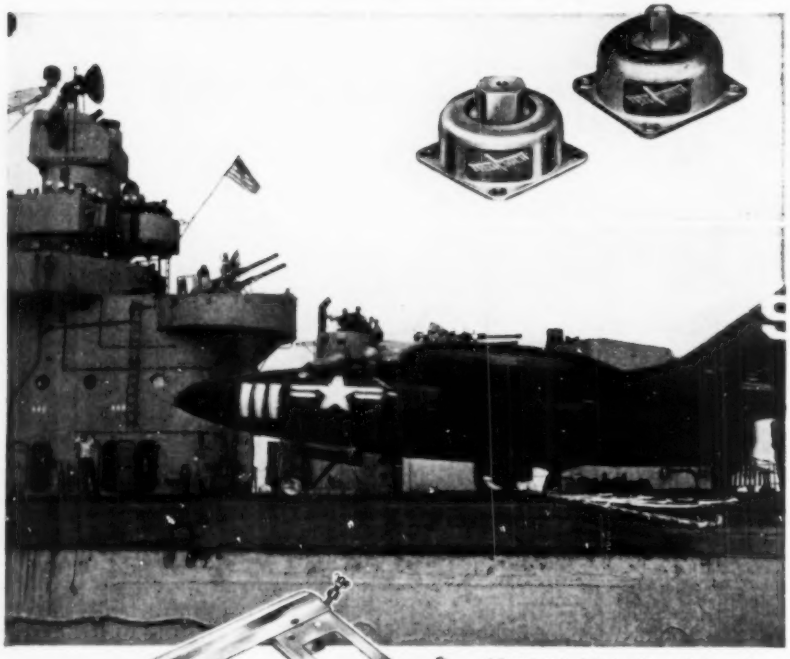
LEADERS IN THE FAN AND MOTOR INDUSTRY SINCE 1890

SHOCK and VIBRATION NEWS

BARRYMOUNTS FOR ASSURED CONTROL OF SHOCK AND VIBRATION

can YOUR equipment stand the shock of carrier landings? Barrymounts can!



Official United States Navy Photograph

New military specifications for all services require ruggedization of your equipments with their mountings.

Ruggedized Air-damped and All-Metl Barrymounts and mounting bases are now available to meet the shock test requirements of specifications MIL-T-5422 (Aer), MIL-E-5272 (USAF), and AN-E-19. These mountings hold your equipment securely and maintain uniform performance characteristics even after the repeated shock of many aircraft carrier landings.

For full information about Barrymounts and bases, write today for your free copy of each of these Barry catalogs:

Catalog #524—Ruggedized Barrymounts and ruggedized mounting bases.

Catalog #523—Air-damped Barrymounts and mounting bases.

Catalog #509—All-Metl Barrymounts and mounting bases.

THE BARRY CORP.

730 PLEASANT ST., WATERTOWN 72, MASSACHUSETTS

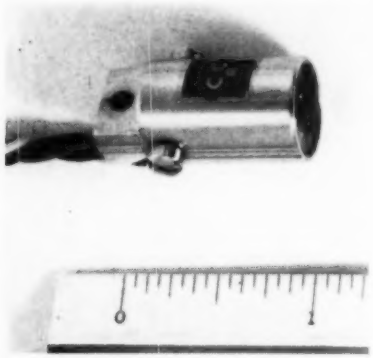
SALES REPRESENTATIVES IN

Atlanta Chicago Cleveland Dallas Dayton Detroit Los Angeles Minneapolis New York Philadelphia Phoenix Rochester St. Louis San Francisco Seattle Toronto Washington

Miniature Magnetic Head

This miniature magnetic head, model HA 102, only $\frac{3}{8}$ in. in dia and 1 in. long, was developed to provide higher component density in magnetic memory storage systems.

The small size increases the number of heads that can be positioned around a magnetic drum, and permits shorter registers. The non-abrasive core, made from hard ferrite, will not injure



magnetic drum coatings in case of accidental contacts, nor will occasional scrapings damage the head.

It operates at frequencies up to 120 kc, having 13.8 mh total inductance, and 11 ohms of d-c resistance, and is stable over wide temperature ranges. It requires 50 ma of writing current and produces 0.4 v of playback voltage from center tap to one end.

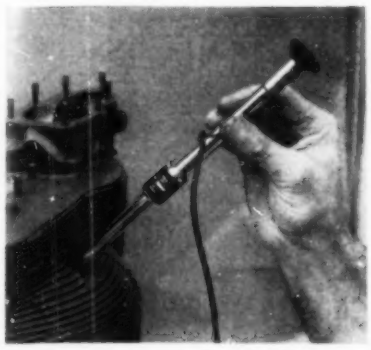
Computer Research Corp., 3348 *El Segundo Blvd., Hawthorne, Calif.*

Borescope For Internal Inspection

The Borescope is a long, tubular, and accurate optical inspection instrument, which has been developed for research and inspection in aircraft and aircraft component plants. It can be used to investigate and inspect the inside walls or surfaces of a hollow casting, such as engine cylinders, and crankcases, which are accessible only through a small hole.

On engine cylinders, the threaded hole for the plug is large enough to insert the borescope, in order to give a clear and illuminated view of the cylinder walls as well as the internal surfaces of the cylinder head. On crankcase, and other hollow castings or housings, a screw hole of half inch diameter will be large enough to perform a complete internal inspection.

The internal walls appear magnified in the optical field of the instrument and it is possible to study the surface



finish, wear and to determine cracks, porosity, corrosion or other important details.

The borescope is a tube of half inch diameter and eighteen inch total length. It can be inserted into a hole of half inch diameter to a depth of one foot. The outside of the instrument is heavily chromeplated. The tube contains a set of twelve corrected, achromatized, fluoride-coated lenses. Their field of vision is 30 deg (included angle).

On the inner end of the lens system is an elliptical first-surface mirror, which has been ground optically, to eliminate distortions of the optical image. The angle of the mirror can be adjusted by hand to either side of its medium position of forty-five degrees. In its normal position, the mirror will produce a view which is at right angle to the borescope tube. The target distance and magnification respectively are listed as follows: 12 in.—2x; 9 in.—2.6x; 6 in.—4x; 3 in.—6.25x. The entire inner wall of a hollow part can be inspected by inserting the instrument to various depths and by rotating the instrument around its own axis.

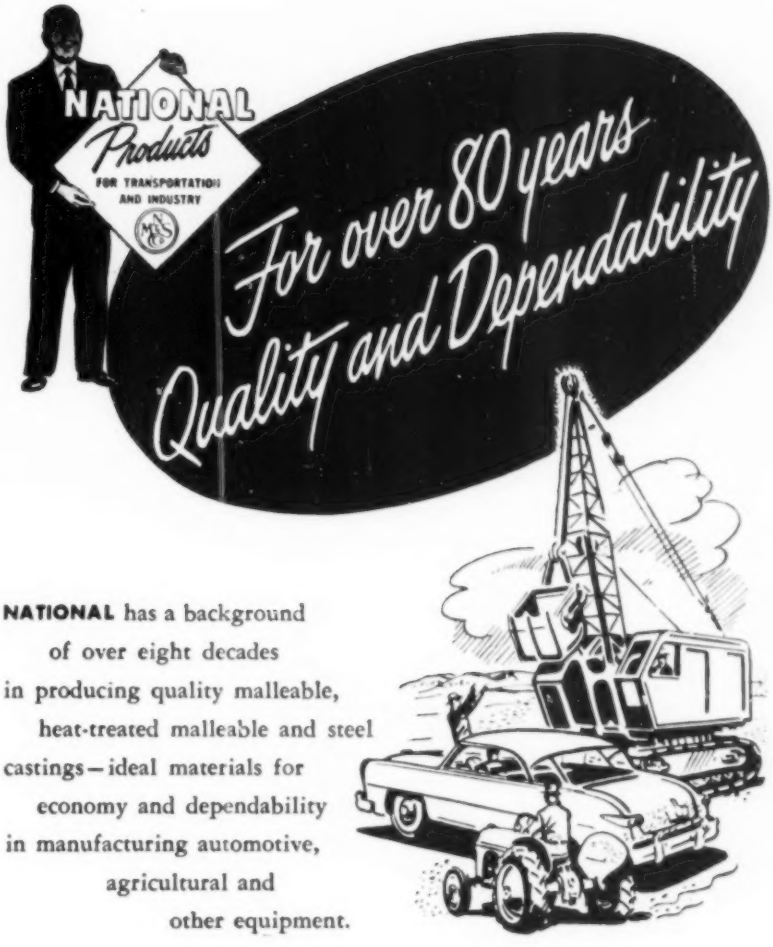
The erecting eyepiece of the borescope has a large eye cup. The eyepiece can be pulled out or pushed in for coarse focusing and can be rotated, to get a fine focus.

For illumination, the borescope uses a 0.35 amp bulb operating on 12 v, and is rated for 250 hours. If brighter illumination is needed, 18 v may be used at a 75 hr lifetime.

Testa Mfg. Co., 418 S. Pecan St., Los Angeles 33, Calif.

Replaceable Cap Lowers Electrode Costs

Electrode costs are lower and critical copper alloy is conserved with this new cap electrode. It consists of a reusable shank and a replaceable cap, the cap being relatively small and



NATIONAL has a background of over eight decades in producing quality malleable, heat-treated malleable and steel castings—ideal materials for economy and dependability in manufacturing automotive, agricultural and other equipment.

NATIONAL's unparalleled experience—coupled with a continuing metallurgical research program, rigorous quality control standards, and completely mechanized foundries in strategically located cities—is at your disposal.

Sales offices and engineering facilities are located at all five plants listed below.

A 16mm technicolor film. Narrated by Edwin C. Hill, this 27-minute film tells how malleable iron is made . . . tested . . . used . . . how its production economy, ductility, machinability, toughness will give you a better finished product. Available for group showings. A-3017

PLANTS LOCATED IN
Sharon, Pa., Cleveland 6, Ohio,
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and Chicago 50, Ill.

NATIONAL MALLEABLE and STEEL CASTINGS COMPANY
CLEVELAND 6, OHIO

RUBBER ENGINEERING BRAINS AT WORK

Primarily, ACUSHNET sells rubber engineering "brains" — specialized, collective engineering skill that produces the solution to problem jobs constantly confronting the users of "precision" molded rubber parts.

ACUSHNET accomplishments in this specialized field of precision-production are widely recognized throughout industry. We count among our customers many of the nation's leading manufacturers, as well as smaller producers of quality products.

Our Engineering Staff will gladly study your prints and recommend stocks with properties to meet specified conditions, or work with your engineers in the initial stages of their designs. Our staff is particularly adept in designing molds that provide maximum production efficiencies and economies.

Acushnet
PROCESS COMPANY

Send for your copy of the "Acushnet Rubber Handbook"

Address all communications to 768 Belleville Ave., New Bedford, Mass.

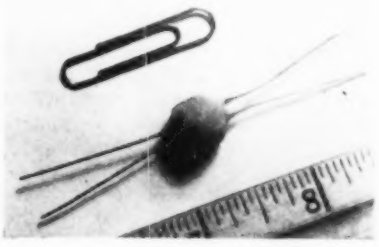
inexpensive in comparison with the conventional one-piece electrode.

When the welding face of the cap electrode is no longer serviceable, it is necessary to replace only the inexpensive cap. A corrugated skirt on the cap provides positive electrical and thermal contact with the shank, while the fluted water hole in the shank assures maximum cooling efficiency. The design of the cap skirt and shank socket provides positive alignment.

P. R. Mallory & Co., Inc., Indianapolis, Ind.

Miniature Pulse Transformers

This miniature pulse transformer is the first of a new series of transformers designed for low power application, to be used where space is a premium. The reduced size is $\frac{7}{16}$ x $\frac{7}{16}$ x $\frac{3}{8}$ in.; one weighs less than 0.1 ounce. The



small size and weight of the unit permits direct mounting with its leads to the chassis.

Special features are said to be fast rise time, with a minimum decay giving a good wave form for specific pulse techniques. Standard frequency response is from 100 KC to 30 megacycles, which can be shifted to a higher or lower frequency range as may be required. These transformers can be built of class "H" materials for continuous operations at 200 C.

PCA Electronics Inc., 6368 DeLongpre Ave., Hollywood 28, Calif.

Pocket Size, Non-Ferrous Hardness Tester

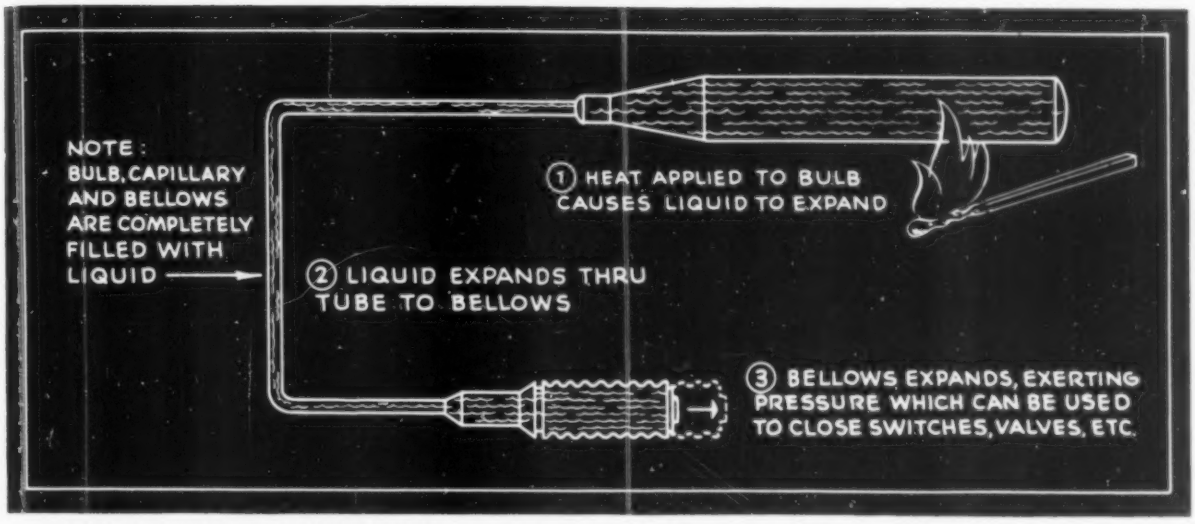
First of its type for the exclusive use of non-ferrous material, this pocket size "on the job" surface hardness testing instrument weighs less than five ounces and measures five inches in length.

Outstanding features include direct reading scales, one incorporates accurately correlated numerical equivalents of the Brinel 500 KG. 10 mm ball testing equipment and meta-

Bellows Digest

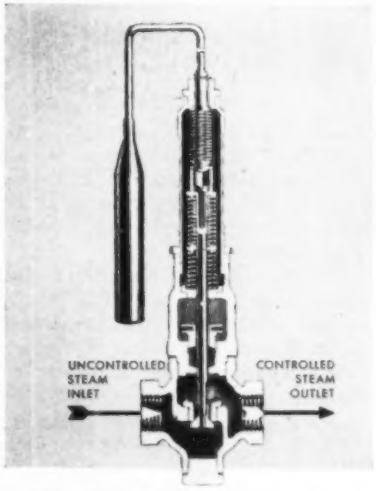
NO. 1. Liquid Filled Bellows Systems for Temperature Control.

- Permits wide temperature range and remote control with one device.


NOTE:
BULB, CAPILLARY AND BELLOWS ARE COMPLETELY FILLED WITH LIQUID
① HEAT APPLIED TO BULB CAUSES LIQUID TO EXPAND
② LIQUID EXPANDS THRU TUBE TO BELLOWS
③ BELLOWS EXPANDS, EXERTING PRESSURE WHICH CAN BE USED TO CLOSE SWITCHES, VALVES, ETC.

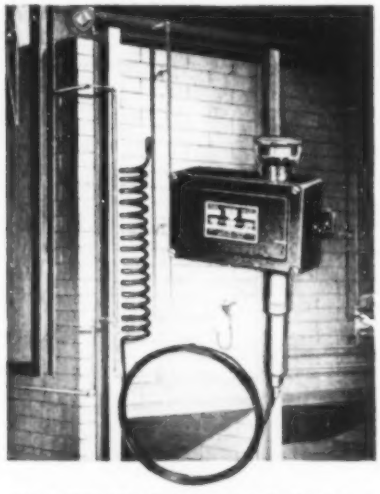
CONTROLLING WIDE RANGE OF TEMPERATURE by means of one adjusting device is a problem solved by a liquid filled Clifford bellows assembly. Such an assembly permits the use of one knob to adjust domestic cooking oven temperatures by remote control from 200° to the top limit of the oven, and industrial oven temperatures to as high as 650° or 700°. It can also be used where temperature range is low.

The bellows movement is closely proportional to the temperature range throughout the entire operating range of the system. The differential required to operate a device is directly related to the range of temperature to be controlled. A device requiring a wide range normally has a wide differential.



CONTROLLING STEAM for use in process equipment is a typical application for Clifford liquid filled bellows assemblies. Cross-section shows a Leslie Temperature Regulator used in cooling service. The rugged, thermostatic element is liquid expansion type with adjustable temperature range as high as 350° F.

DESIGNERS OF CONTROLS FOR ELECTRIC AND GAS RANGES use Clifford liquid filled bulb and bellows assemblies to control temperature. Bellows movement is used to operate switches that turn electrical heating elements on or off — or to turn valves on or off in controlling flow of gas.



ALL KINDS OF INDUSTRIAL PROCESSES requiring temperature or pressure control benefit by using Clifford bellows assemblies. Pictured here is a typical installation by United Electric Controls Company. This company uses Clifford bellows assemblies in temperature control of ovens, kilns, steam tables, kettles and similar equipment.

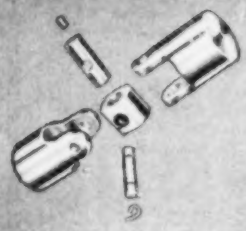
MAYBE YOU, TOO, CAN BENEFIT from the use of Clifford Hydron Bellows Assemblies. Besides controlling temperature, these flexible, leakproof, metallic bellows are also used to: (1) seal rotary shafts or packless valves against liquid or gas leakage; (2) transmit motion hydraulically to remote points; (3) provide for thermal expansion in many types of applications; (4) provide shock mountings or vibration dampening; (5) permit motion in a vacuum.

Write Clifford Manufacturing Company, 122 Grove Street, Waltham 54, Massachusetts. *Division of Standard-Thomson Corporation.* Sales offices in New York 17, Detroit, Chicago 1, Los Angeles.

Fewer Parts make Easy Assembly

Simple construction, fewer parts make assembly and disassembly easy – also mean longer life.

CURTIS UNIVERSAL JOINTS



Simple construction is not the whole story. A combination of modern design, wise choice of alloy steels, with a special heat treatment for each part, give greater strength with less weight. And you can depend on Curtis catalog ratings – they are based on hundreds of actual tests.

ONLY CURTIS OFFERS ALL THESE ADVANTAGES

Availability – 14 sizes always in stock.

Simplicity – fewer parts, simpler construction.

Government Tests – complete equipment for government tests in our plant.

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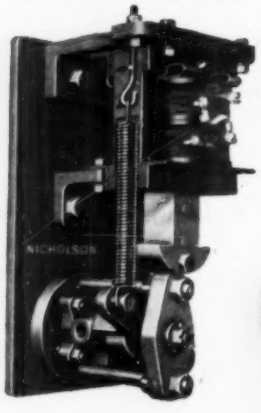
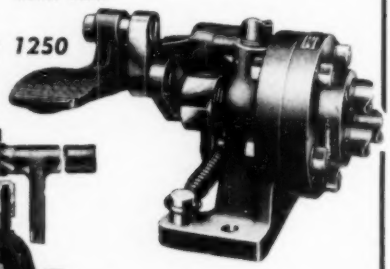
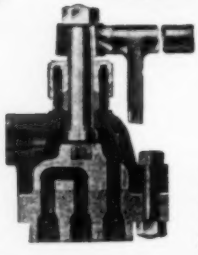
Nicholson Valves for Any Pressure Medium

Nicholson control valves offer maximum adaptability. A rubber processor reports that they carry only 1 spare valve for each 52 in service. Unlike many poppet or balanced piston valves, they can be used for steam as well as air, gas, oil, or water. Specially treated hard seats and easy repacking cut maintenance time.



Send for Catalog 1250





Lever, foot, solenoid, motor types; size ¼" to 2½"; press. to 5000 lbs.

200 Oregon St., Wilkes-Barre, Pa.

W. H. NICHOLSON & CO.

TRAPS · VALVES · FLOATS

lometer scale. The metalometer scale is graduated numerically in 100 equal divisions and is to be used as a comparator for all accepted non-ferrous master specimens.

Peabody Industries, Inc., 12129 Hamilton Ave., Detroit 3, Mich.

Unbonded Resistance Wire Strain Gage

The unbonded resistance wire strain gage is now available for the measurement of tensile and compressive strains. This instrument provides a useful means for strain measurement in structural testing, experimental stress analysis, and strength of materials research.

The strain gage is furnished with knife edges for specimen engagement, and exhibits electrical characteristics similar to those of the cemented type.

The overall dimensions are approximately 2¼ in. long x ¾ in. wide x ¾ in. high. Two active bridge arms are incorporated, and the instrument may be operated with strain indicators of all types currently used with bonded strain gages.

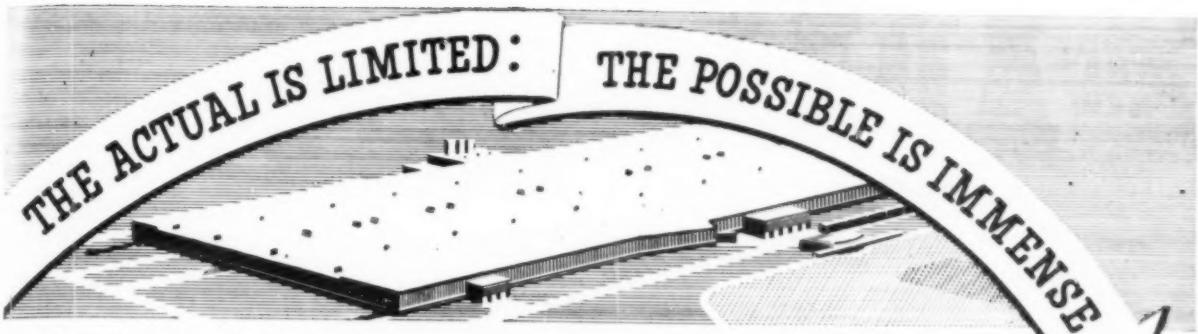
The principal advantages of this unbonded strain gage are that it may be used immediately upon attachment to the specimen and that it may be used repeatedly without destruction of the strain gage.

Statham Lab., Inc., 12401 W. Olympic Blvd., Los Angeles, Calif.

Automatic Filter-Drain for Compressed Air Lines

A filter-drain has been developed which provides automatic removal of liquids and solids from compressed air lines, with automatic drainage of collected liquids. It is designed for use in air lines to portable air tools, air cylinders and air-powered machines where removal of liquids and solids from air lines is required, and where manual draining is not desired or practical.

One of the improvements over previous filter and drain units is said to



NEW LINCOLN PLANT CREATED BY INCENTIVE-INSPIRED CO-ACTION IN DEVELOPING POSSIBILITIES IN PRODUCT

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WELDED DESIGN IMPROVES APPEARANCE

. . . while cutting costs 50%

BY converting to welded steel, this progressive manufacturer has achieved a more modern, better selling appearance for his products. At the same time he has cut costs 50% on some components.

Pleasing appearance in a product generally indicates efficient use of materials in its design. With welded steel, cumbersome and often costly dead weight, inherent with gray iron, is essentially eliminated. Wall thicknesses in steel are of exact design size. In addition, steel can be shaped at low cost with simple shop equipment.

While attaining stronger, more rigid products, in addition to improved appearance, savings in materials alone often run as high as 85%. Your Lincoln representative can show you how to apply the cost-saving benefits of steel to your products. Call or write.

Fig. 3. Steel-Designed Blower *built by The Boardman Company, Oklahoma City, Oklahoma. Eliminates milling and drilling operations . . . is easier to clean and paint.*

Incentive Management—A thought-provoking approach to developing greater teamwork between employee and employer. Written by James F. Lincoln. Price only $1.00 postpaid in the U. S. A.; $1.50 elsewhere.

PROPER DESIGN IN WELDED STEEL ALWAYS IMPROVES PRODUCT AND LOWERS COST

Fig. 1. Original Construction. *Required 41% more metal than present welded steel design. Heavier weight with gray iron added to handling costs in shop, in shipping and final installation.*

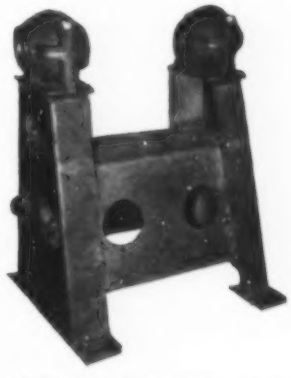


Fig. 2. Present Weldesign in Steel. *Saves 50% on cost. Has better appearance . . . greater selling appeal. Is stronger . . . more rigid.*

HERE'S MORE PROOF

Machine Design Sheets are available to designers and engineers. Write on your letterhead to Dept. 34.

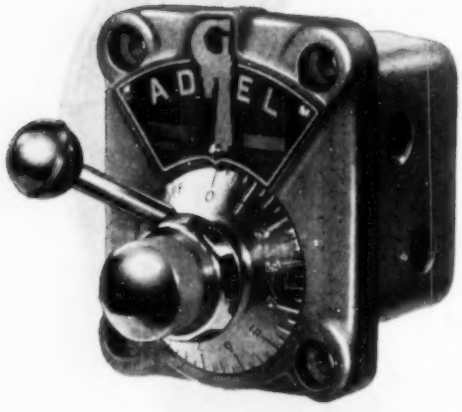
THE LINCOLN ELECTRIC COMPANY

CLEVELAND 17, OHIO

The World's Largest Manufacturer of Arc Welding Equipment

THE NEW **ADEL**

FLOW CONTROL VALVE FOR VERSATILITY



Adjustable from completely shut off position to 25 G.P.M. maximum flow. Will maintain constant fluid flow and constant machine feed over a wide range of pressures and feed resistances.
The diagrams show but two of innumerable circuits and systems where this versatile and better valve can be used to advantage.

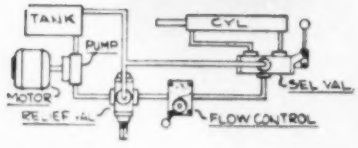


Diagram illustrates typical circuit showing control of cylinder.

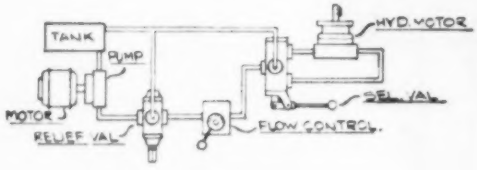


Diagram illustrates typical circuit showing control of hydraulic motor.
8 model variations are available—¾ in. Pipe Size—1, 2, 4 & 6 G.P.M. Flow Max.
¾ in. Pipe Size—10, 15, 20 & 25 G.P.M. Flow Max.

CHARACTERISTICS

1. Valve is compensated type which maintains substantially a constant flow regardless of variation in inlet and outlet pressure.
2. Maximum recommended inlet pressure 1500 P.S.I.
3. Maximum recommended outlet pressure equals inlet pressure minus 100 P.S.I.
4. No drain line required.
5. Wide range of control lever rotation (270°) permits extremely accurate flow settings.

A FEW SELECT TERRITORIES ARE STILL AVAILABLE TO PROGRESSIVE DISTRIBUTORS OF HYDRAULIC EQUIPMENT. INQUIRIES INVITED.

For complete engineering specifications and counsel, Address: ADEL DIVISION—GENERAL METALS CORPORATION, 10767 Van Owen Street, Burbank, California

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DIVISION OF GENERAL [illegible]PORATION · Burbank, Calif.

Manufacturers of Industrial Hydraulic Control Equipment

DISTRIBUTORS: AIR & HYDRAULIC CO., NEW HAVEN, CONN. • RUSS CHAMBERLIN COMPANY, PORTLAND, OREGON • J. BOYD COATES, PHILADELPHIA, PA. • FRANK T. DONNELLY COMPANY, PITTSBURGH, PA. HASKEL ENGINEERING & SUPPLY CO., SAN FRANCISCO, CALIF. • HASKEL ENGINEERING & SUPPLY CO., GLENDALE, CALIF. • HYDRAULIC BRAKE SUPPLY CO., PHOENIX, ARIZ. • LINCOLN SUPPLY CO., PROVIDENCE, R. I. • SCOTT EQUIPMENT AND ENGINEERING COMPANY, DAYTON, OHIO • H. F. SODERLING CO., SEATTLE, WASH. • ROBERT TAYLOR & SONS, SALT LAKE CITY, UTAH • WYATT SALES COMPANY, CLEVELAND, OHIO • CORBY SUPPLY COMPANY, ST. LOUIS, MO. • INDUSTRIAL AIR & HYDRAULIC EQUIPMENT CO., DETROIT, MICH. • HYDRAQUIP CORPORATION, HOUSTON, TEX.

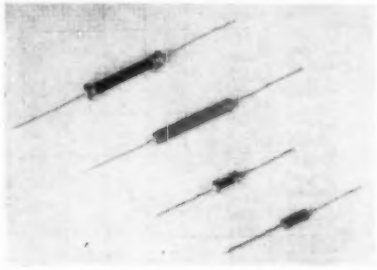
be its automatic operation under constant or fluctuating air pressure and air flow. It also continues to operate when the flow of air is cut off. This feature assures drainage of condensate in air lines when equipment is shut down. Any sludge or solid particles in the air are filtered out before the air goes to the drain chamber eliminating the possibility of clogging the drain or causing the drain float to stick.

This new unit is available in ¼ in., ⅜ in., and ½ in. pipe thread sizes for in-line pipe connection installations. It is recommended for a flow of 0-35 cfm at pressures from 0-150 psi in temperatures from 40 to 120 F.

C. A. Norgren Co., Englewood, Colo.

High Frequency Carbon Resistor

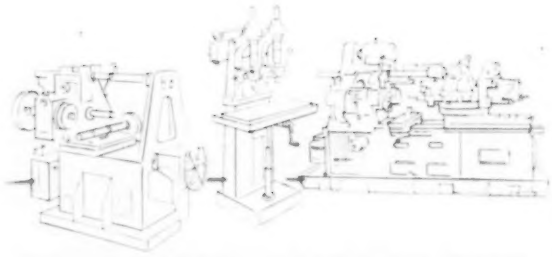
The Carb-ohm, a deposited carbon resistor, may be used for high-frequency applications, particularly where high resistance is needed, or power dissipations up to 2w are required. The resistors are also suitable for electronic equipment which is subject to extremes of temperature. Carb-ohms come hermetically sealed in glass or in humidity-impervious casings. They are available with a threaded stud or tapped hole terminal, as well as the axial lead shown.



Phaostron Co., 151 Pasadena Ave., South Pasadena, Calif.

Flush Latch for Heavy Duty Applications

A new flush latch is being produced for heavy duty applications where rugged, severe service conditions exist in access panels and inspection doors on heavy equipment and interior and exterior surfaces of all types of aircraft. The bolt contains a spring-loaded button that allows for variations in closure contact and misalignment, insuring tight closure of access panels and doors. The latch opens only when direct pressure is applied to it. The operating trigger is large enough to



YOU DON'T ALWAYS NEED MACHINE TOOLS FOR FINISHED MACHINE PARTS

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With OILITE YOU:

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- Over 20 Years Production Experience
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Oilite Products include: BEARINGS, Finished Machine Parts, Cored and Solid Bars, Permanent Filters, and Special Units.

AMERICAN CHEMICAL PAINT COMPANY

AMBLER CHEMICALS ACP PROCESSES PENNA.

Technical Service Data Sheet

Subject: HOW TO MAKE PAINT STICK TO GALVANIZED IRON WITH LITHOFORM®

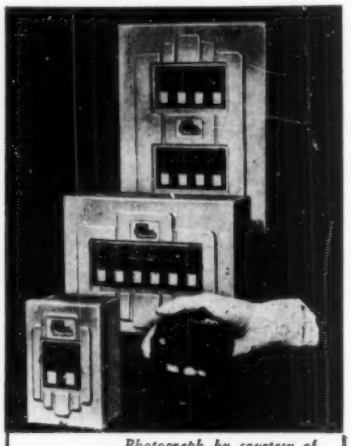
INTRODUCTION

"Lithoform" forms a dense, zinc phosphate coating on zinc, cadmium, and galvanized surfaces—including Galvanneal, cadmium plated steel, zinc plated steel, zinc base alloys, and zinc base die castings. The "Lithoform" coating, which is non-metallic and inactive, retards reaction between alkaline metal oxide and the paint film. Peeling and loss of adhesion are thus greatly retarded on painted Lithorized zinc and cadmium.

ADVANTAGES OF "LITHOFORM"

"Lithoform" forms a durable bond for paint. It is economical. It eliminates frequent repainting. It protects both the paint finish and the metal underneath. "Lithoform" meets these Government Finish Specifications:

QQ-P-416
RR-C-82
MIL-E-917A (Ships)
JAN-F-495
AN-F-20
U.S.N. Appendix 6



Photograph by courtesy of Murray Manufacturing Corp.

Murray Circuit Protectors are fully magnetic and provide maximum protection for both domestic and industrial wiring. Housings are of galvanized iron which is Spray Lithorized for long paint life.

THE LITHORIZING PROCESS

"Lithoform" can be applied by brushing or spraying the work with simple hand equipment, by dipping it in tanks, or by spraying it in industrial power washers.

Brush. Galvanized bay windows, cornices, rain gutters, hardware, building siding, truck panels, and farm equipment are typical of the many surfaces that are treated effectively with Brush "Lithoform".

Dip. This grade is used for coating cleaned surfaces of such typical products as cabinets, refrigeration condensers, etc., immersed in heated solutions in tanks.

Spray. The spray process is the most logical one with which to coat sheets, coiled strip or duplicate products best processed on a conveyor.

CHEMICALS ACP PROCESSES

WRITE FOR FURTHER INFORMATION ON "LITHOFORM" AND ON YOUR OWN METAL PROTECTION PROBLEMS.

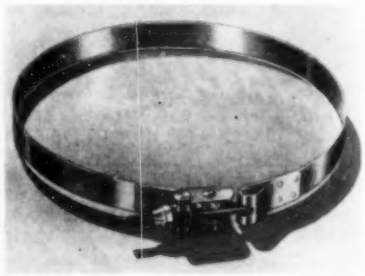
CHEMICALS ACP PROCESSES

make the latch open even when the operator is wearing gloves. The new H-5150 is made of heavy gage stainless, coated coal-rolled steel or heat treated aluminum combinations.

Hartwell Co., 9035 Venice Blvd., Los Angeles 34, Calif.

Stainless Steel Quick Assembly Clamp

A new stainless steel clamp, known as the series 21 quick coupling clamp, features a new hinged latch for quick



assembly or removal, and is especially designed for convenience in handling removable equipment. It offers an efficient seal for all types of hose and duct connections. The design used in the latch assembly to give strength is combined with its all stainless steel construction to make it suitable for high temperature, pressure and corrosion resistance. Its producers also claim a high strength-to-weight ratio.

Specialty Products Co., 1965 E. 66th St., Cleveland 3, Ohio

Pocket-Size Drafting Equipment

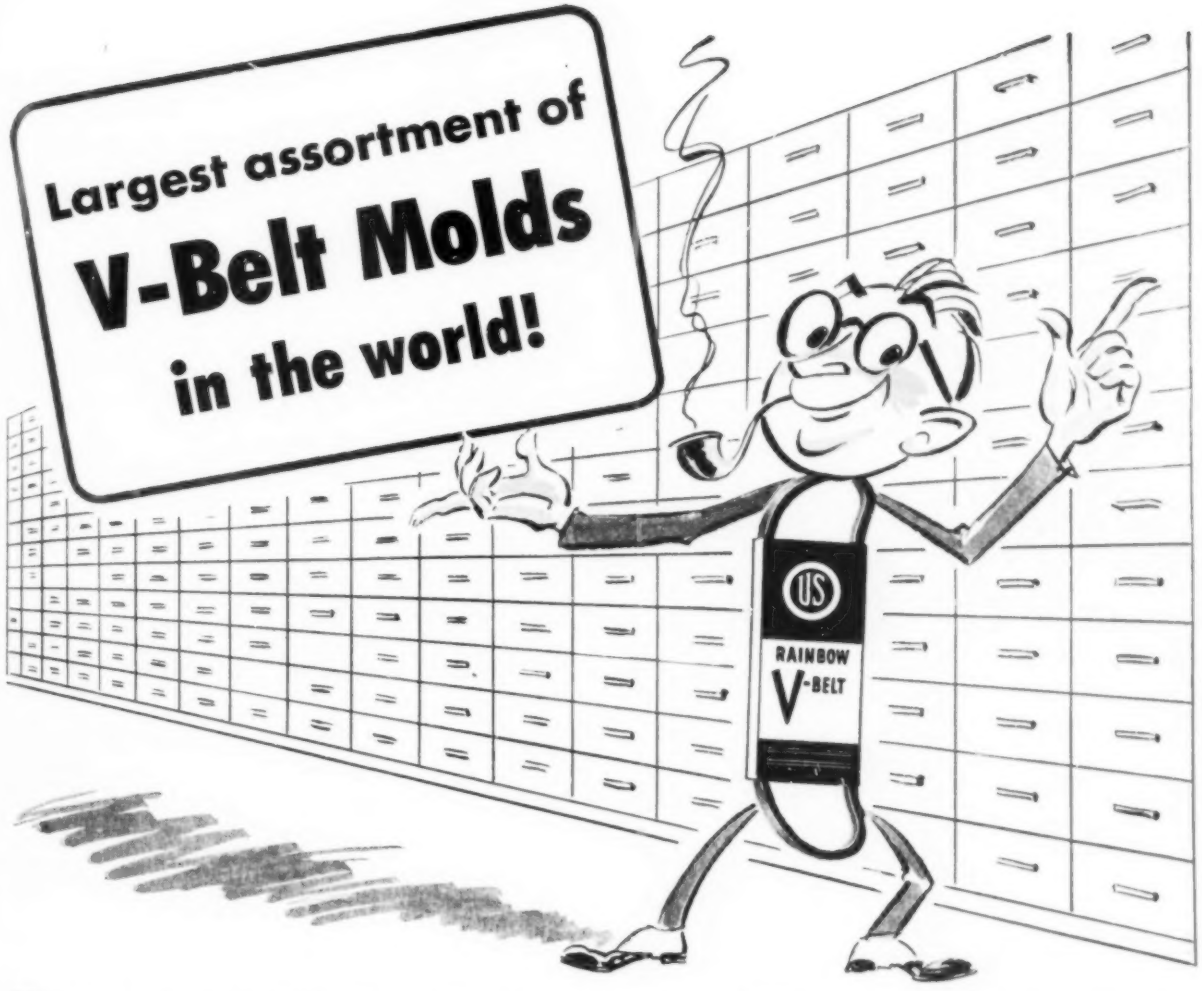
A new basic drafting device called the paraline is small enough to be carried in a pocket, and is different from all old models. The metal parts are now incorporated in one section, which is said to eliminate the slippage found in other models. The paraline has a T-square, straight edge, triangle, protractor, a 32d in. scale, and parallel rules all in one unit. The instrument measures $10\frac{1}{4}$ x $3\frac{1}{16}$ inches.

Loomis Ind., Box 442, Berkeley 1, Calif.

Strength of Fiber Glas Increased

A new finish has been developed to overcome the loss in mechanical strength of glass fiber reinforced polyester laminates and moldings that is caused by exposure to moisture. It

Largest assortment of V-Belt Molds in the world!

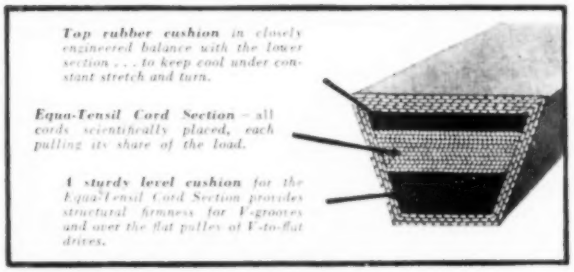


THAT'S WHY, if you want a "special" in a hurry, a U. S. Rubber belt usually can be obtained without making a new mold. You get the fastest possible delivery of your specific belt.

"U. S." engineers will compound belts with special properties to withstand conditions not usually found on the average drive—oil, high temperatures, generation of static electricity, to name but a few.

"U. S." V-Belts have practically no stretch. Before leaving the factory, the inherent stretch has been worked out by mechanical means. But sufficient elasticity is retained to enable the belts to withstand severe shock loads. Extra pulling power is gained by means of straight sidewalls, which grip the grooves for complete contact the full height of the belt. Protective jackets increase the grip while keeping out the dirt and prolonging life.

Finally, each belt has the unique U. S. Rubber development which provides efficient pull and strength for diverse operations—the famous Equa-Tensil Cord Section. Order from your jobber, or for more information, write to address below.


Top rubber cushion in closely engineered balance with the lower section . . . to keep cool under constant stretch and turn.
Equa-Tensil Cord Section — all cords scientifically placed, each pulling its share of the load.
A sturdy level cushion for the Equa-Tensil Cord Section provides structural firmness for V-grooves and over the flat pulleys of V-to-flat drives.

A COMPLETE DRIVE SERVICE
MULTIPLE V-BELTS
F. H. P. BELTS • SHEAVES
FLAT BELTING AND BELTING
SPECIAL PURPOSE BELTS

PRODUCTS OF
U.S.RUBBER
SERVING THROUGH SCIENCE

UNITED STATES RUBBER COMPANY
MECHANICAL GOODS DIVISION • ROCKEFELLER CENTER, NEW YORK 20, N. Y.

Nothing is as smooth as a
HOOVER HONED RACEWAY*

POLISHED
Polished Raceway surface magnified 100 times as used in other ball bearings
* HOOVER HONED
Raceway surface magnified 100 times, as used exclusively in Hoover Ball Bearings.

It's the raceway that makes the difference

HOOVER
America's only
BALL BEARING
with Honed Raceways

90% longer life
30% greater load
Amazing Quietness

The Aristocrat of Bearings

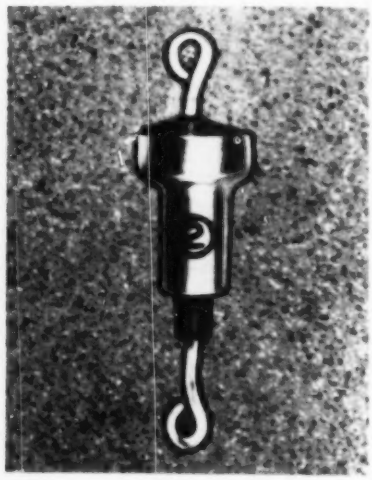
HOOVER BALL AND BEARING CO.
ANN ARBOR, MICHIGAN

is said that with this finish, stronger parts are produced and new applications of glass fiber products are possible. After prolonged immersion in water, glass fiber parts covered with this finish showed a loss in mechanical strength of less than 10 percent, and in some cases less than 5 percent.

Garan Chemical Corp., 7213 Santa Monica Blvd., Los Angeles 46, Calif.

Small Ferrule-Type Feed-Thru Capacitor

Type 503 C, a small feed-thru ceramic capacitor for filtering leads passing through a chassis, has, for protection again humidity, a small resin sealed ceramic disk element in a recessed cup at the top of the metal ferrule. The thru-lead passes through



a hole in the center of this dielectric disk. Therefore, there is equal radial distribution to the grounded outer shell of all the high frequencies being by-passed.

Rated at 500 v d-c, capacitance values of the new units range up to 100 mf.

Sprague Electric Co., North Adams, Mass.

Double Pole, Double Throw Coaxial RF Switch

A new compact, double pole double throw coaxial RF switch replaces two single pole double throw switches and offers a saving in weight and flexibility of installation. The switch is motor operated instead of solenoid. Straight end connections eliminate the use of enefficient angle connectors, and save time and space. The unit is also easy to mount.

The switch has: a frequency range

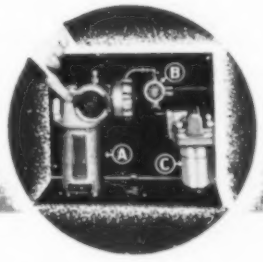
Fights Friction!... with new efficiency...
...new simplicity...new savings!

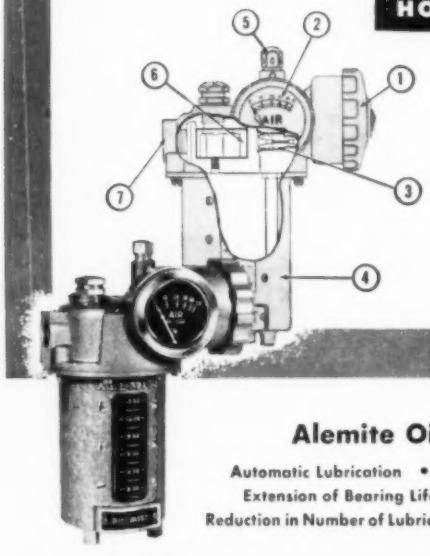
ALEMITE OIL-MIST LUBRICATION

Greatly extends bearing life!
Air pressure seals bearings! . . . Stops oil drippage!

WHAT IT IS: Alemite Oil-Mist is a completely automatic system of airborne lubrication for machinery application. It is an amazingly simple lubricator which applies a clean, constant, uniform oil film to groups of bearings designed for either oil or grease lubrication.

A unique lubrication system. Oil-Mist operates on compressed air – the lubrication unit has no moving parts. A basic system consists of (a) Lubricator, (b) Solenoid Control, (c) Water Separator, and bearing fittings and tubing.





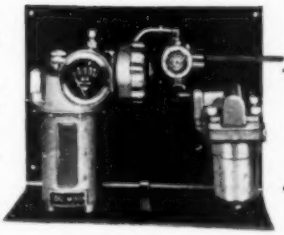
HOW IT WORKS: **The Oil-Mist Lubricator atomizes oil into microscopic particles which are carried in the air stream and distributed through tubing to bearings.**

Oil-Mist airborne lubrication is accomplished this way: Compressed air entering the unit passes through air regulator (1) and air gauge (2). As this air passes through venturi (3) it draws oil from reservoir (4). Oil flow is set by knob (5). The mixture of air and oil from the venturi is thrust against baffle (6). Only the most minute, lighter than air particles are blown through outlet (7) into delivery line to lubricate bearings.

Alemite Oil-Mist offers all these lubrication advantages

Automatic Lubrication • Continuous Lubrication • Eliminates Guesswork • Consumption of Oil Cut 90%
Extension of Bearing Life • Stops Oil Drippage • Reduction of Bearing Temperatures • Greater Safety
Reduction in Number of Lubricants • Protection from Contamination • Elimination of "Down-Time" • Manpower Savings

LUBRICATOR SPECIFICATIONS:



- Oil-Mist outlet ½" fem. p.t. Air gauge registers to 50 psi. Operating air pressure – 5 to 20 psi.
- Air regulator reduces from pressures up to 200 psi. Normal air consumption – .7 to 1.2 cfm.
- Range of oils handled – to 1,000 sec. (S.U.V.) @ 100°F.
- Oil reservoir capacity 12 oz. (approximately 1 week supply). Intake filter screen – 70 mesh. Fill plug – 5/16".
- Material – die cast aluminum body with nylon plastic window.
- Baffle-type water separator – automatic self-dumping. Requires no manual attention – no filter elements to replace. Air inlet ¼" fem. p.t.

delivers oil to bearings *3 ways*

1. Oil-Mist as Such. Most commonly applied to any type of anti-friction bearing – ball, roller or needle.

2. Oil in Spray Form. For open and enclosed gears and chains. Spray nozzle partially condenses mist into semi-liquid form and directs the spray onto a concentrated area.

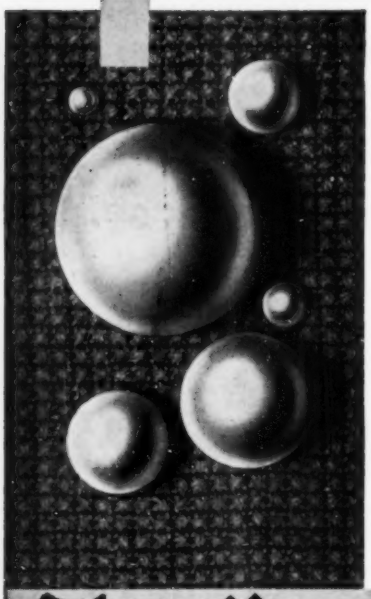
3. Oil in Liquid Form. For plain bearings, slides, ways, vees, cams and rollers. In these applications, condensing fittings are used.

A PRODUCT OF SW STEWART WARNER

Just out! This new Oil-Mist Catalog and Engineering Data Book. Write now for your FREE copy. Alemite, Dept. T-42, 1850 Diversey Parkway, Chicago 14, Illinois.

Alemite OIL-MIST Lubrication

IN Size and Spherical Accuracy
Perfection of Surface
Uniformity—Dependable Physical Quality



NOT A BETTER BALL MADE..

And the service results from every Strom metal ball prove it—not only in the finest precision ball bearings but also in the lot of other ball applications where Strom balls are doing the job better.

Strom has been making precision metal balls for over 25 years for all industry and can be a big help to you in selecting the right ball for any of your requirements. In size and spherical accuracy, perfection of surface, uniformity, and dependable physical quality, there's not a better ball made.

Strom STEEL BALL CO.
1850 So. 54th Ave., Cicero 50, Illinois
Largest Independent and Exclusive Metal Ball Manufacturer

LET NEY EXPERIENCE AND EXPANDED PRODUCTION FACILITIES SOLVE YOUR CONTACT PROBLEMS

CONTACTS, brushes, wipers, slip rings, commutator segments and similar components for electrical instruments and apparatus represent a field in which Ney Research has a long list of important accomplishments. Ney precious metal alloys specially developed for these applications are widely and very successfully used. And now enlarged manufacturing facilities have been added to meet the steadily increasing demand. If you have applications in any of these categories, write at once for the Ney Technical Data Book No. R-12. Or call our Engineering Department outlining your needs.

THE J. M. NEY COMPANY • 109 Elm Street
HARTFORD 1, CONNECTICUT

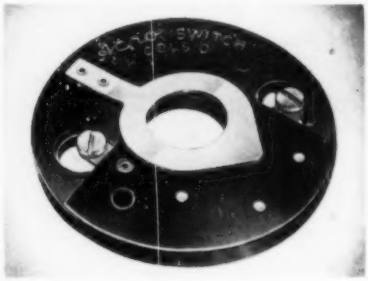
up to 11,000 Mc./sec; V.S.W.R. less than 1.3 to 1; insertion loss less than 0.5 db throughout operating range; attenuation between unused connectors 55 db average; motor driven actuator rating 24-28 v d-c.

Various models are available for most aircraft applications requiring efficient performance under extreme temperature and shock conditions. Switches are precision built to exacting military specifications.

Transco Products Inc., 12210 *Nebraska Ave., Los Angeles* 25, *Calif.*

Starting Switch for Fractional Hp Motors

To overcome starting winding switch failures, caused by foreign matter becoming lodged between the exposed contacts of the switch, a totally enclosed starting winding switch has been developed having snap action



mechanism. With this design, dirt is sealed out, positive operation is assured, and control at the changeover point of the motor is improved.

The switch in the illustration is 2.8 in. in diameter, and 0.5 in. thick. This unit is designed to be mounted around the motor shaft and directly operated by a centrifugal unit. The housing is black thermosetting plastic.

Acro. Mfg. Co., 2040 *E. Main St., Columbus, Ohio*

Electrical Tubing With Good Flexibility

Known as silicone rubber coated fiberglas tubing, this electrical tubing is a class H product having good flexibility and heat endurance. It will withstand exposure of 200 hrs at 200 C without becoming brittle.

This new tubing is manufactured by using selected sizes of glas braid, which are coated with silicone rubber using a special multiple coat process to insure uniform coating and roundness.

Irvington Varnish & Insulator Co., 6 Argyle Terrace, Irvington 11, *N. J.*

GITS Unit* SEAL
Now STANDARDIZED

For . . .

Gear Reduction Units
Aircraft Reciprocating Engines
Automotive Accessories
Jet Propulsion Units
Washing Machines
Standard & Special Machine Tools
Electrical Power Equipment
Business Machines

If *you* have a shaft sealing problem, Gits experience in these and many other specific applications can prove of great and immediate value to you.

Write today for FREE illustrated Brochure, or send us your seal problem.

*Cartridge Seal . . . pressure balanced . . . requiring only 25% more space than lip-type seals.

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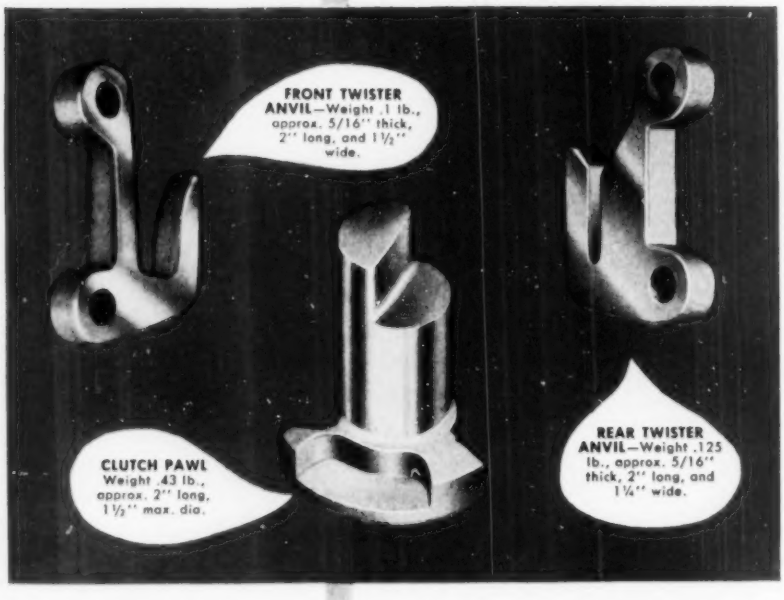
1838 S. Kilbourn Ave. • Chicago 23, Ill.

Gits Lubricating Devices,
The Standard For Industry For Over 40 Years

Microcast®...

CUTS MACHINING COSTS ON NEW FARM BALER


FRONT TWISTER ANVIL—Weight .1 lb., approx. 5/16" thick, 2" long, and 1½" wide.
CLUTCH PAWL Weight .43 lb., approx. 2" long, 1½" max. dia.
REAR TWISTER ANVIL—Weight .125 lb., approx. 5/16" thick, 2" long, and 1¼" wide.

READY TO USE

The three Microcast parts shown above are being used virtually as cast, with only a finish grinding operation required for completion. Made from AISI 4615 carburizing grade steel, they are smooth, dimensionally uniform, and structurally sound as cast.

●

MICROCAST is the precision process originated by Austenal Laboratories, Inc., for the production of castings of intricate design using the high melting point alloys where surface smoothness and dimensional uniformity are mandatory, requiring little or no machining.

Precision Castings Lower Cost

To effect considerable savings in machining costs on their new Automatic Wire-Tying Baler, Pennsylvania's New Holland Machine Company wisely chose Microcast parts for three vital components. Also contributing to those savings was the complete development engineering assistance rendered by our Microcast Division, a skill developed through almost 25 years of pioneering in precision castings. Perhaps you have a similar problem coming up . . . why not get full Microcast information today?

MICROCAST PRECISION CASTINGS PROCESS

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AUSTENAL LABORATORIES, INC.
224 East 39th St., New York 16, New York
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MEETINGS

April 21-22

AMERICAN ZINC INSTITUTE—Thirty-Fourth Annual Meeting, Hotel Statler, St. Louis, Missouri.

April 21-24

SOCIETY OF AUTOMOTIVE ENGINEERS—National Aeronautic Meeting and Aircraft Engineering Display, Hotel Statler, New York.

April 24-25

SOCIETY FOR ADVANCEMENT OF MANAGEMENT — Time Study and Methods Conference, Hotel Statler, New York.

April 29-30

METAL POWDER ASSOCIATION — Eighth Annual Meeting and Show, Drake Hotel, Chicago, Ill.

May 5-16

BRITISH INDUSTRIES FAIR—London and Birmingham, England. New York Offices, 30 Rockefeller Plaza, New York 20, N. Y.

May 8-9

AMERICAN INSTITUTE OF INDUSTRIAL ENGINEERS—Methods Improvement Clinic, Dayton, Ohio.

May 10

AMERICAN INSTITUTE OF INDUSTRIAL ENGINEERS—Annual Convention, Dayton, Ohio.

May 12-14

INSTITUTE OF RADIO ENGINEERS—National Conference on Airborne Electronics, Dayton Biltmore Hotel, Dayton, Ohio.

May 14-16

SOCIETY FOR EXPERIMENTAL STRESS ANALYSIS—Spring Meeting. Hotel Lincoln, Indianapolis, Ind.

May 22-24

AMERICAN SOCIETY FOR QUALITY CONTROL—Annual Convention, Onondaga County War Memorial Auditorium, Syracuse, N. Y.

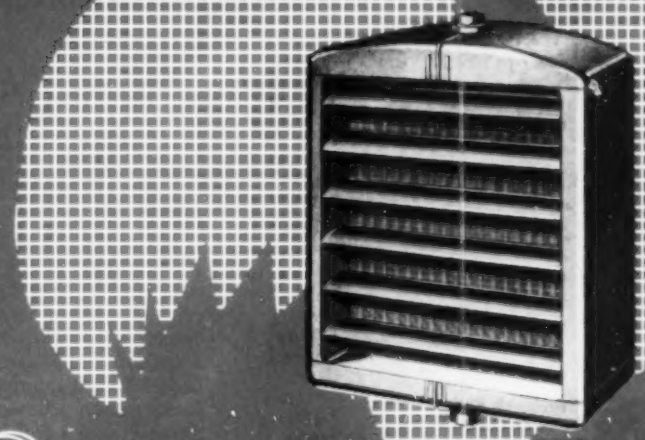
June 1-4

AMERICAN GEAR MANUFACTURERS ASSOCIATION—Annual Meeting. The Homestead, Hot Springs, Va.

June 15-19

AMERICAN SOCIETY OF MECHANICAL ENGINEERS—Semi-Annual Meeting, Sheraton-Gibson Hotel, Cincinnati, Ohio.

unit heaters to air filters



Wire Cloth

FOR HEATING, VENTILATING

AND AIR CONDITIONING APPLICATIONS

- Unit Heaters
- Exhaust Fan Guards
- Oil Burning Heating Appliances
- Floor Furnaces
- Air Conditioning Units
- Electric Humidifiers
- Electric De-Humidifiers
- Air Purifiers
- Electric Air Circulators
- Air Filters

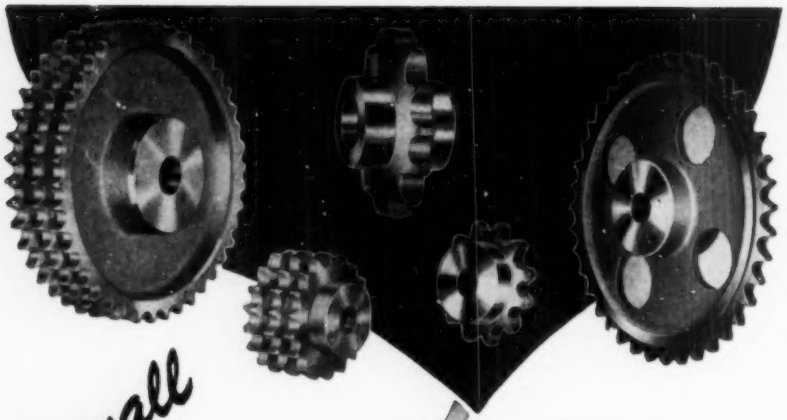
The weather-cock changes direction with every wind. Reynolds wire cloth changes, too. Always in the right direction, but according to plan. Because Reynolds engineers change the wire cloth to meet exact specifications and particular needs of the heating, ventilating and air conditioning industry. Or any manufacturer-user of wire cloth, whether he makes automobiles, farm implements, electrical appliances, kitchen tools. Reynolds engineers believe in progressive change—always working out new ways and new wires that may mean new help to you in bettering your product. Consult them; no obligation.

REYNOLDS WIRE DIVISION, NATIONAL-STANDARD CO
DIXON, ILLINOIS

Divisions of National-Standard Co.

ATHERIA STEEL—*Clifton, N. J.*—Flat, High Carbon, Cold Rolled Spring Steel
NATIONAL-STANDARD—*Niles, Mich.*—Fine Wire, Fabricated Braids and Tape
WAGNER LITHO MACHINERY—*Jersey City, N. J.*—Lithographing and Special Machinery
WORCESTER WIRE WORKS—*Worcester, Mass.*—Round and Shaped Steel Wire, Small Sizes

NS NATIONAL-STANDARD Company NILES, MICHIGAN



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★SPEEDY SERVICE
★COMPLETE LINE
★PRECISION BUILT

If your product will permit a standard pitch, look it up in the Sewall Catalog of Stock Sprockets. Or let us send you an estimate on your special design. True running, durable gears and sprockets all add up to over-all quality in Sewall products.

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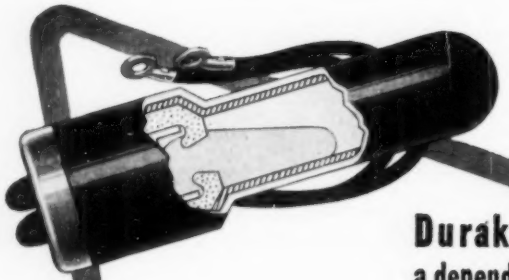

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Durakool
a dependable

10 YEAR SWITCH

Steel-clad with mercury to mercury contacts, the Durakool hydrogen filled switch is performing with sensational dependability.

★ Millions of contacts without a falter
★ Positive "Make and Break" contact action
★ Withstands high temperatures
★ No deterioration in storage
★ Seven new models—1 to 65 amperes
★ Smaller in size, increased capacity

Send for BULLETIN 525

Steel Durakool
MERCURY SWITCHES

See Telephone Directory for Local Distributor or write
Durakool, Inc. Elkhart, Indiana

Sans, Souci

Ad Libbing By the Editor

How to Make a Million

The fortune is made not by the original inventor but by the entrepreneur who takes the idea, embellishes it and gets somebody to buy it. It doesn't make much difference what the idea is worth. The big thing is to get a fancy price for it. The question then is how to put across the new idea and get fame and fortune. The process is relatively simple and for the benefit of readers of inventive mind who wish to be their own promoters it is being set forth here in considerable detail.

The first step is to get a big idea. This is not hard because every idea is a small idea at the time of its inception. Therefore the procedure is to get a small idea and then magnify it and after it has been properly magnified it is then multiplied. When this is done with acumen the idea finally develops into a real big overwhelming something that promises to revolutionize the world. The idea must be pictured to cause thrones to totter, empires to expire and to revolutionize completely all existing standards, practices and the status of the art.

Having nourished the embryonic idea to proper gigantic stature through the medium of imagination unfettered with facts, the next step is to clothe it with a suitable vocabulary. This is the first of the several crucial steps involved and to accomplish it properly is of the nature of an art. The vocabulary should use mostly Anglo Saxon words with just a faint sprinkling of manufactured words and unrelated facts.

It is the manufactured words that have the greatest potency as is so clearly demonstrated in advertising. By a simple rule it is relatively easy to manufacture words by the process of "mixing syllables". For example, take the two words elasticity and gyration. Mixing the syllables and dropping a few of them we get "elastiration" which will mean anything you want. Practice the pronunciation so you can say it glibly. Another good combination is to mix up a few nucleonic words such as "fission", "neutron" and "electron" which jumbled up together come out "neutrosion". I don't know what it means but it sounds awfully good especially when applied to some mysterious process. For example, "By this newly discovered principle of elastira-

THE SHADOW of QUALITY...

CAST BY STALWART RUBBER PARTS!

The quality of the components determines the performance of the finished product . . . and STALWART custom-engineered rubber parts are mass-produced to the highest standards. Various compounds have been developed which retain their physical, chemical and dielectric properties regardless of the effects of extreme temperatures, oil and gasoline, chemical action, abrasion or weather.

STALWART rubber compounds are supplied in precision molded, extruded, die-cut and lathe-cut shapes for application in aircraft, automobiles, trucks, marine equipment, railroad rolling stock, processing equipment, electrical assemblies, and other equipment.

Precision-fabricated parts can have varying degrees of hardness, tensile strength, and elongation to meet individual, S.A.E. or A.S.T.M. specifications.

Write today for the new 16-page illustrated catalog Number 400-SR for additional details.

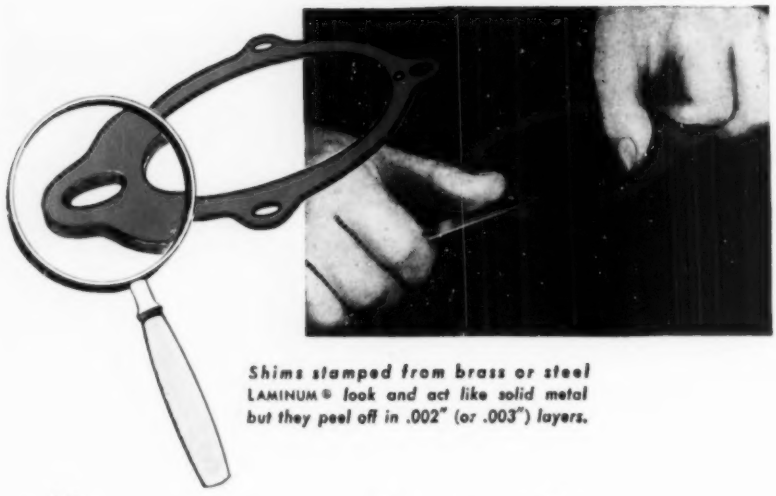
400-SR

STALWART RUBBER COMPANY

200 Northfield Road • Bedford, Ohio

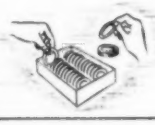
LAMINATED SHIMS

SIMPLY PEEL FOR ADJUSTMENT



Shims stamped from brass or steel LAMINUM® *look and act like solid metal but they peel off in .002" (or .003") layers.*

Provide great accuracy yet allow easy machining tolerances



No counting

Speed production by simplifying your spacing adjustments

No stacking

Reduce lathe time; no standby machine required during assembly

No miking

Adjustments right at the job by peeling laminations with a penknife

Precision cut to your exact specifications, with careful quality control

URGENT! Save production time! Shims are more important now than ever!
SEND TODAY for our Engineering Data File

LAMINUM
THE SOLID SHIM THAT peels FOR ADJUSTMENT

LAMINATED SHIM COMPANY, Inc.
1404 UNION STREET GLENBROOK, CONN.

CUSTOM SHIMS STAMPINGS SHIM STOCK

tion we have achieved the long sought neutrosion of the electron with its negative nucleus. Thus it is that we have created this world shaking new alloy 'elastirium' with its amazing properties."

The next step is to select some material that is quite new but has been frequently mentioned in newspapers and literature. At the present time Germanium is an excellent one. You can mention it and attribute certain mysterious properties to it which it may or may not possess and then set it up as a criterion to illustrate how your new material or idea possesses certain far superior properties and promises to greatly excel Germanium. Of course you don't have to know much about Germanium because all of your listeners will assume that you are an expert on the subject and they will fear to dispute you lest they show their ignorance.

The next ingredient in your prospectus is to include a few historical items. That phase of it can be made up entirely from the imagination and you can also rest assured that no one will dispute you because everyone will assume that what you are talking about is a phase of history which they have not studied. Again your listeners will refrain from showing their ignorance.

Having built the prospectus with great care the next step is to find the prospects to whom you are going to sell your idea. Here it will be necessary first to set up carefully drawn specifications as to who the prospect should be. Among the essential specifications are the following:

1) The prospects must have money of which you might possibly relieve them.

2) They must be men who pride themselves on their knowledge, education and business acumen.

3) They must be high up in the organization of which they are a part.

4) They must have nothing more than a superficial knowledge of the subject of your idea.

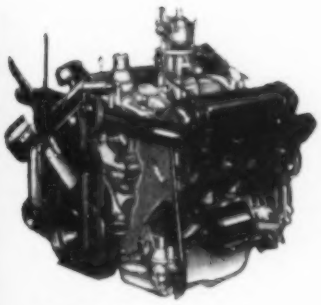
5) They must be gullible.

It is imperative that the men approached be in high position and pride themselves on their knowledge, education and business ability. With these attributes the men will hesitate to be too positive in disputing your claims and assertions lest they "guess" wrong and expose their own ignorance and shortcomings or lack of business courage.

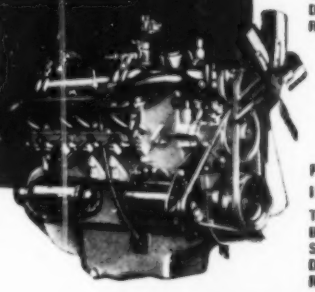
Having selected the audience, the ground work must be laid to "put across" the idea. To put it across successfully requires several elements. Besides the bigness of the idea and its great promise of profit and glory, it

FORD ANNOUNCES THREE NEW *Heavy Duty* INDUSTRIAL ENGINES

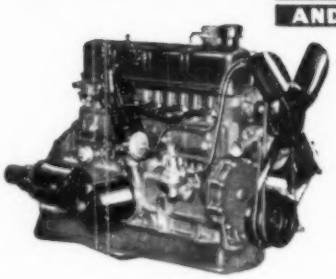
Ford
INDUSTRIAL ENGINES
AND POWER UNITS



FORD "317"
INDUSTRIAL ENGINE
Type—V-8, 90° Overhead Valve.
Bore—3.8 inches.
Stroke—3.5 inches.
Displacement—317 cu. in.
Rating (dyn.)—140 b.h.p. @ 2800 rpm.



FORD "279"
INDUSTRIAL ENGINE
Type—V-8, 90° Overhead Valve.
Bore—3.56 inches.
Stroke—3.5 inches.
Displacement—279 cu. in.
Rating (dyn.)—125 b.h.p. @ 2800 rpm.



FORD "215"
INDUSTRIAL ENGINE
Type—6 cylinder Overhead Valve.
Bore—3.56 inches.
Stroke—3.6 inches.
Displacement—215 cu. in.
Rating (dyn.)—93 b.h.p. @ 2800 rpm.

Designed and Built for INDUSTRIAL APPLICATIONS

● Now, manufacturers and users of industrial powered equipment have a choice of six great Ford engines . . . all especially designed for industrial applications and incorporating notable advancements for still greater performance and operating economy. With the three new series pictured here and three series in the present line, there is a choice of six engines ranging from 120 to 317 cu. in. displacement.

Our experienced Sales Engineers are at your service in developing engineering recommendations for the most efficient use of Ford Industrial Power in your application.

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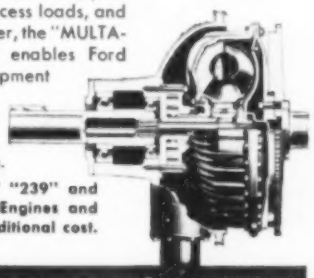
The new Ford "MULTA-TORQUE" Converter offers all the advantages of fluid coupling PLUS torque multiplication. Designed to absorb shock loads, prevent stalling under excess loads, and start bigger loads faster, the "MULTA-TORQUE" Converter enables Ford Engines to power equipment normally requiring much larger, more costly engines in the same applications.



Available with "215," "239" and "254" Ford Industrial Engines and Power Units at low additional cost.

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All six engines in the 1952 Ford Line are available as assemblies or complete Power Units, closed or open type.

Ford Industrial Engines and Power Units are RIGHT 3 WAYS for your job!

1. **RIGHT POWER** for your job—six great engines available in both Power Units and Engine Assemblies.
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3. **RIGHT SERVICE**—Ford Industrial Engine Service is **Nationwide.** Parts obtainable quickly from your nearest Ford Dealer.

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FORD MOTOR COMPANY
15050 Woodward Ave., Highland Park 3, Mich.

We are interested in Industrial Power for:

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(state your application)

Send us 1952 literature on Ford Industrial Engines checked below:

☐ "120" 4-Cyl. ☐ "215" 6-Cyl. ☐ "239" V-8
☐ "254" 6-Cyl. ☐ "279" V-8 ☐ "317" V-8
☐ "MULTA-TORQUE" Converter

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...can't hurt ACE molded parts

Because ACE hard rubber is completely unaffected by most chemicals and doesn't object to water in the least, it's ideal for parts like this rayon candle filter.

One of the strongest plastics (tensile up to 10,000 psi.), ACE hard rubber is good for *tough* jobs, too. Easy to machine (the threads above, for example), easily polished (like your faithful ACE comb), it does a better job at lower cost in thousands of parts from bearings to magneto parts and water meter pistons. We can mold it for you, extrude plain and fancy shapes, supply sheets for punched parts, line or cover metal with it, and even make large, intricate parts by hand-wrapping.

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American Hard Rubber Company

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must be presented as something mysterious. And to clinch the deal in a hurry, you must be prepared to convince your prospects that they must decide immediately to accept the proposition as there are others ready to jump at it.

After you are fully prepared you make the arrangement for a preliminary hearing with the selected sheep that are to be sheared. You must make certain that this will be nothing more than a preliminary hearing, very secret and the audience confined only to the immediate principals. At this hearing you make the presentation which you have rehearsed many times. You throw out all the million dollar words with great fluency and assurance. You emphasize the mysteriousness of the new invention and give some kind of an explanation to show the difficulty of understanding the idea. You sympathize with them over the fact that even people in the highest realms of science will have great difficulty in understanding this new idea. By adroitness you suggest that there be a meeting with some of the technical heads of the company to give you the opportunity to present it to them. But you repeat the difficulty of understanding your super scientific discovery. The subsequent meeting is then set for a date in the near future with everybody sworn to secrecy. This last is of greatest importance.

Knowing some of the technicians who have been selected for the secret hearing you approach the most gullible one and sell him on the great virtues of this idea and casually drop the remark that one of their strongest competitors is after you. You don't tell him much but impress upon him that it can not be expected for him to understand the idea completely in such a brief meeting because after all you have worked twenty years to develop it. By good salesmanship you at least get him to the point of a tentative acceptance and sow seeds in his mind that his company must act quickly.

Then comes the pay-off. The meeting is all arranged. You come to the meeting with a determined expression mixed with a slightly worried look. When it comes your turn to deliver the case you announce you have learned that another individual has by accident hit upon something that might lead him to the same idea and therefore it would be most essential that the group proceed immediately with its commercial development. Of course you make it plain that the other individual still has months to go before he becomes dangerous and might never discover the principle.

Corrosion Was a Problem

UNTIL THEY SWITCHED TO MAYARI R

The medicine cabinets and waste receptacles in Bennett Manufacturing Company's line were originally made of mild carbon steel. And, like most products containing this grade of steel, they presented a corrosion problem. For instance, rust would often concentrate at one or two spots and cause considerable damage long before a receptacle or a cabinet had served its expected life.

To solve this problem and to improve their competitive position, Bennett began using low-alloy, high-strength Mayari R. This grade of steel was not expensive and it offered excellent resistance to corrosion. Longer life and all-around better service resulted—they have used Mayari R in their products ever since.

Tests show Mayari R to have from 5 to 6 times the atmospheric corrosion-resistance of plain carbon steel—and 2 to 4 times that of copper-bearing steel. Besides this, it retains paint 20 to 80 pct longer than carbon steel, depending, of course, upon the type of paint used.

No matter what you manufacture, it will pay you to investigate this versatile grade of steel. Our Catalog 259 explains in detail how Mayari R has been used to advantage in products ranging from locomotives to flatirons. Write for a copy.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. Export Distributor: Bethlehem Steel Export Corporation

BETHLEHEM STEEL

Mayari R *makes it lighter... stronger... longer lasting*

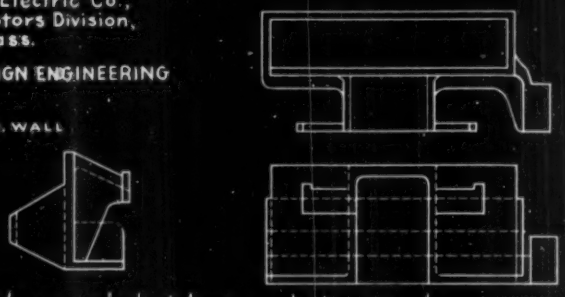
WANTED: closer tolerances reduced costs

SUGGESTED - BRUSH HOLDER

General Electric Co.,
Small Motors Division,
Lynn, Mass.

Att: DESIGN ENGINEERING

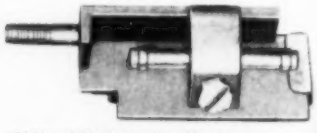
.076 MIN. WALL



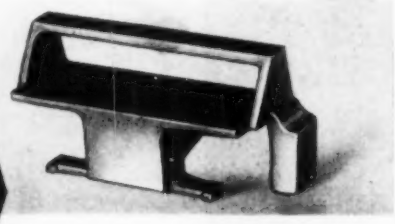
This design is the best from production standpoint
We could produce it to reflect credit
on both companies. E.B. Atlantic Casting

The production of a light weight, rugged brush holder for use with aircraft generators posed a problem for General Electric. They wanted a high-quality, rigid brush holder at reduced cost, produced by a process that afforded closer control of tolerances.

Atlantic was consulted and the recommendations they made on the brush holder design provided more than ample strength. The Atlantalloy process provided the close tolerances and lower cost.



Old brush holder designed by General Electric for use on aircraft generators.



New brush holder designed in collaboration with Atlantic engineers and produced by the Plaster Mold Process.

WRITE for a copy of "Quality Precision Castings for Industry" on your Company letterhead. This booklet explains how the plaster mold process cuts production costs, and includes specifications on Atlantic's alloys.

CASTING and ENGINEERING CORP.

Sans, Souci.....continued

With your beautiful prospectus worked up, your manufactured vocabulary, your references to history, your illusion to similar great developments now in the public eye and last but not least positive statements of the glory and the profit involved, you force the issue with a statement something like this:

"And now gentlemen, the time for action is now. For reasons I cannot divulge, it is essential that we proceed at once. (The gullible guy into whose ear you buzzed has undoubtedly told them that the hated competitor wants to steal it away.) You recognize it is impossible for me to clarify completely all of the great possibilities inherent in this great new alloy, fisonium, with its amazing properties of elastiration and neutrosion. But men in your position with your vast background of experience can readily see that this alloy is the only solution to unsolved problems in the manufacture of isotopes, reactive jets, fission derivates and a host of others. Just as Edison's lamp lighted the way for the development of the great electrical industry, so will fisonium bring to the home the immeasurable benefits of neucleonics.

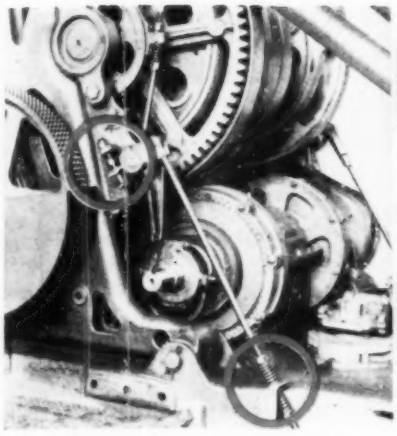
"It is necessary to make available to me immediately $100,000 so that I will be able to compile all my supporting data, make two great experiments to provide the needed confirmations for patent applications and to enroll in this project a selected group of scientists."

Never ask for less than $100,000 as that is about the minimum worthy of consideration by top management. In fact, at the last annual meeting of the Association of Entrepreneurs it was recommended that in view of inflation the minimum asking price should be advanced to $250,000. Two members reported gratifying success with this figure.

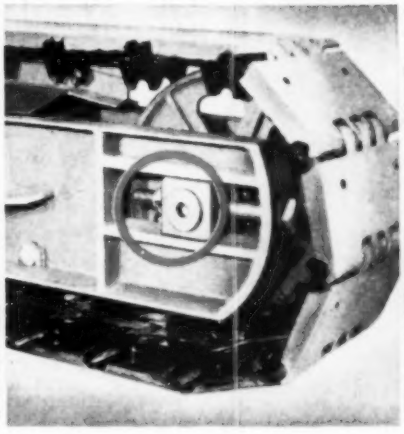
If you have done the job well you can class yourself with Six-Hundred-Percent Miller, Ivan Kreuger, Get-Rich-Quick Wallingford, Ponzi of Boston and a host of others. How well you get away with it will depend largely on how intelligently you have conducted the operation and how well you have fortified yourself against redress. On that score, always remember that the wife who got stuck by the door-to-door salesman didn't even tell her husband that she had been gypped.

Note:—We have available a very limited supply of the book, "How to Cultivate Suckers and Make Millions" at $100.00 per copy. No C.O.D. orders accepted. Get yours before the supply is out. —G. F. N

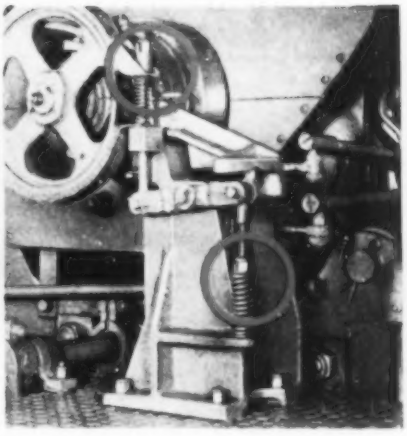
For a nut that won't vibrate out of adjustment



LOCKS ANYWHERE . . . Spring-loaded reach-rod and stop lever on this new General Excavator shovel depend on Elastic Stop Nut's positive gripping action. The elastic collar permanently positions the nut anywhere on the bolt to accurately maintain spring-loaded settings.



VIBRATION-PROOF . . . Idler tumbler on this new shovel must maintain constant tension against crawler belt. An Elastic Stop Nut holds it firm in the face of vibration and heavy impact loads. The Famous Red Elastic Collar hugs threads, damps out vibration



EASILY ADJUSTED . . . On applications like these, General Excavator has provided its customers with the easy, sure method of adjustment —Elastic Stop Nuts. These nuts take hair-fine adjustment in the field or in the factory—and hold it indefinitely.

use Elastic Stop nuts

This newest earth mover of the General Excavator Company is 100% equipped with Elastic Stop Nuts. At 750 key spots General Excavator simplified assembly with these standard fasteners—offers customers less maintenance, easier maintenance.

Elastic Stop Nuts are supplied with integral locking collars of nylon or fiber—permit multiple reuse—have military, naval, and air force approvals. For design information on Elastic Stop Nuts, contact your local ESNA representative, or mail the handy coupon to Elastic Stop Nut Corporation of America, 2330 Vauxhall Road, Union, N. J.

Elastic Stop Nut Corporation of America is also maker of the ROLLPIN

ROLLPIN

Dept. N3-42, Elastic Stop Nut Corporation of America
2330 Vauxhall Road, Union, N. J.

Please send me the following free information on ESNA self-locking fasteners:

- ☐ AN-ESNA conversion chart
- ☐ Elastic Stop Nut Bulletin
- ☐ Rollpin bulletin and sample Rollpins
- ☐ Here is a drawing of our product. What self-locking fastener would you suggest?

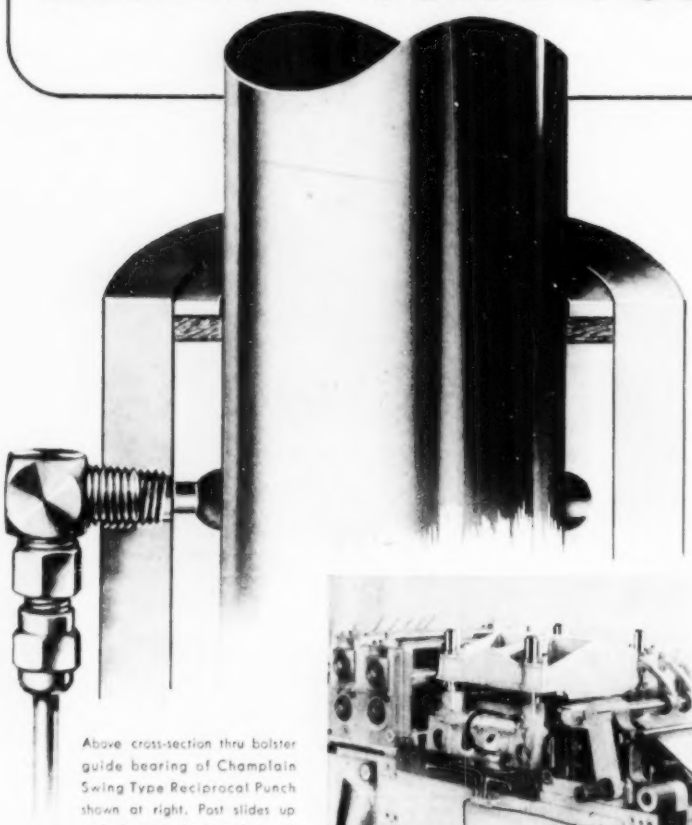
Name _____ Title _____

Firm _____

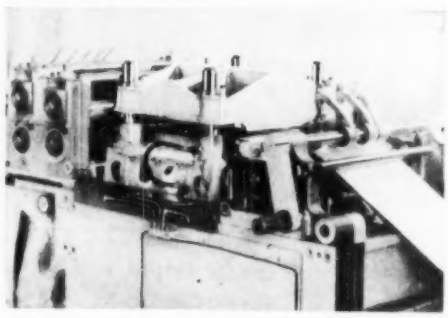
Street _____

City _____ Zone _____ State _____

How to LUBRICATE A VERTICAL GUIDE POST



Above cross-section thru bolster guide bearing of Champlain Swing Type Reciprocal Punch shown at right. Post slides up and down in bushing but not below annular groove.



...the way CHAMPLAIN does it with a BIJUR SYSTEM

Keeping a constant oil film between the guide post and bushing was the problem here. It is solved by cutting an annular groove in the bushing . . . controlling the oil flow thru a meter-unit at the drilled passage . . . supplying a measured volume of oil from an automatic lubricator which force-feeds oil to all four guide posts and 47 other punch bearings. This is another example of Bijur "teamwork for bearing protection." For aid in solving your lubrication problems, call in a Bijur engineer.

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BIJUR

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ENGINEERING ABSTRACTS

Heat-Resisting Sintered Aluminum

Abstracted from Heat-Resisting Sintered Aluminum by R. Irmann, *The Engineers' Digest* (England) January, 1952.

ALUMINUM POWDER can be produced by atomization of the liquid metal, by vibration of the near-liquid hot metal, or by dry or wet crushing. The first two methods result in equi-axial grains, usually of about 200 microns (8×10^{-3} in.) linear size, and the last two methods in flakes of 1 to 50 micron thickness or under special conditions, of even less than 1 micron thickness. Ordinary commercial aluminum forms an oxide skin on exposure to air, the thickness of the skin increasing with time of exposure. The powder is first compressed cold under a pressure of 12 to 30 tsi, then sintered at 500 to 600 C under a pressure of 30 tsi, and finally extruded or die-pressed at the same temperature and under a pressure of 30 to 60 tsi. The strength of the sintered product at room temperature is many times that of cast aluminum and comparable to heat treated Al-Cu or Al-Mg alloys. Fig. 1 shows the mechanical properties of products sintered from powders

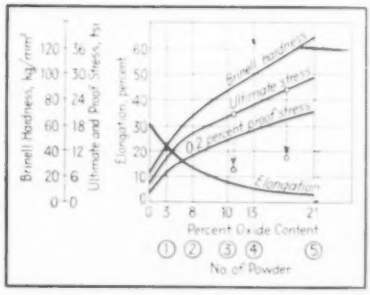


FIG. 1—Influence of oxide content and fineness of aluminum powder on the mechanical properties of the sintered product at room temperature.

of varying fineness (No. 5 being the finest powder) and values for Al-Cu and Al-Mg are given as a comparison; the figures for zero per cent oxide are those of the cast metal. These qualities are due to the oxide skin enveloping each individual powder particle. On sintering, the skin is broken and the particles weld together, perhaps only at single points, but nevertheless so as to give sufficient cohesion to the

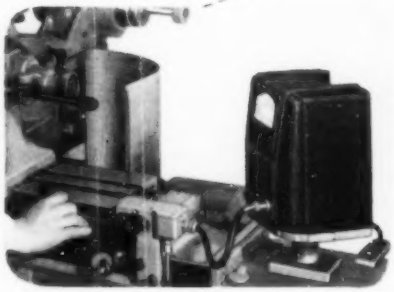
Build "*tenths of tenths*" measuring into your equipment

Versatile Brown & Sharpe Electronic Measuring Equipment is easily adapted to your machine or fixture design. It provides fast, accurate setting or gaging to .00001" *with human error practically eliminated.*

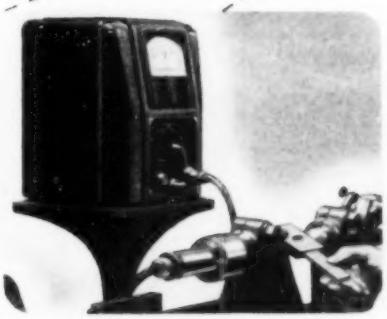
An outstanding advantage is the separate amplifier unit which isolates heat-producing elements, preventing temperature drift in gaging units. It's economical, too — you can design inexpensive Gage Head Cartridges into several fixtures and use the same amplifier for all of them. True linear response of the amplifier eliminates the need for "go" and "no go" masters — just "zero" the pointer on initial set-up and read variations directly from the accurately graduated dial.

These are but a few of the many advantages of Brown & Sharpe Electronic Measuring Equipment. Write for detailed Bulletin. Brown & Sharpe Mfg. Co., Providence 1, R. I., U. S. A.

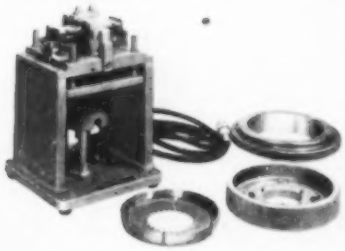
Brown & Sharpe Electronic Amplifier No. 950 for .0001" to .00001" readings. Gage Head Cartridge No. 953 is plugged in.



Electralign — an application of this precision electronic equipment in Brown & Sharpe's own grinding machines. Permits fast, accurate setting of swivel table for precision grinding straight work or exact tapers after a single trial grind.



Gage Head Cartridge No. 953 mounted on fixture to measure a fixed gage . . . used with Amplifier No. 950. Standard comparators for external or internal measuring also available.



Special fixture utilizes Gage Head Cartridge and Amplifier to measure internal angle accuracy to ± 1½ seconds independently of bore size and without reference to locating surface.

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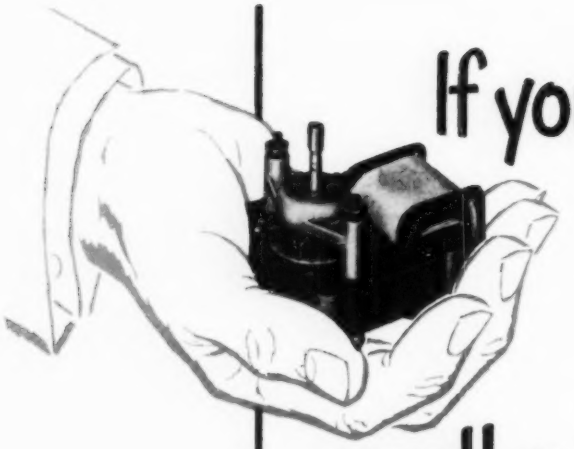

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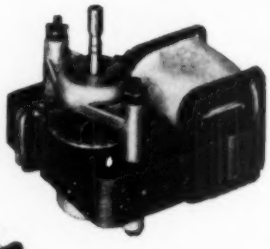
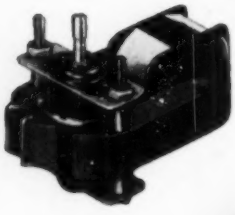
- Record changers
- Kitchen exhaust fans
- Small unit heaters
- Timing devices
- Window ventilators

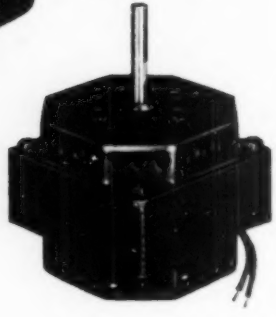
MODEL A
2-pole induction type





MODEL C
2-pole induction type

MODEL D
4-pole induction type



THE GENERAL INDUSTRIES CO.
DEPARTMENT MM • ELYRIA, OHIO

product. Since the oxide skin still isolates each particle over most of its circumference, recrystallization or grain growth are inhibited even at elevated temperatures. Thus, while heat treated alloys lose their strength by heating at 400 C, the properties of the sintered product remain unaffected even by prolonged heating at 500 C.

If an aluminum powder of a fineness between No. 3 and No. 4 is sintered, and the sintered product tested at an elevated temperature after being held for one month at that temperature, then its strength is seen to decrease, though not at the same rate as that of a heat treated Al-alloy. The elongation of the sintered product also decreases while that of the recrystallising alloy increases very steeply. The superior heat resistance of the sintered unalloyed aluminum is still more strikingly displayed by the fact that, if tested at room temperature after one month's heat treatment at 500 C, the sintered product loses practically none of its strength (Table I). Even after very prolonged heat treatment at 250 C, its proof stress remains unimpaired. The creep qualities of sintered aluminum are also superior to those of Al-Mg alloy.

Table I. Mechanical Properties at Room Temperature After Prolonged Heating

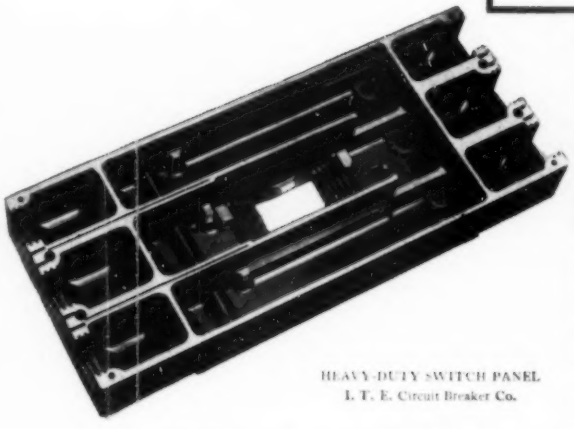
Material	Sintered aluminum	Al-Cu alloy	Al-Mg alloy
Treatment	extruded after 1 mth at 500 C	quenched, tempered after 1 day at 400 C	quenched, after 1 day at 400 C
Ultimate stress tsi	21–23 20–22.5	21–27 6.5–9	26–31 12–16
0.2 Percent Proof stress tsi	15–17.5 14–17	17.5–25 2.5–5	17–23 5–8
Elongation percent	6–8 6–8	10–14 20–30	12–20 10–20
Brinell Hardness kg/mm²	100–110 95–105	90–120 30–40	100–125 50–65

The main advantage of sintered aluminum for the design of machinery will be its heat resistance. It would form an excellent material for engine pistons because of its heat resistance, thermal conductivity, small thermal expansion and absence of permanent volume change. Moreover, its melting point is appreciably higher than that of Al-alloys, so that overheating (e.g., in Diesel engine pistons) is less likely. The high temperature fluctuations in

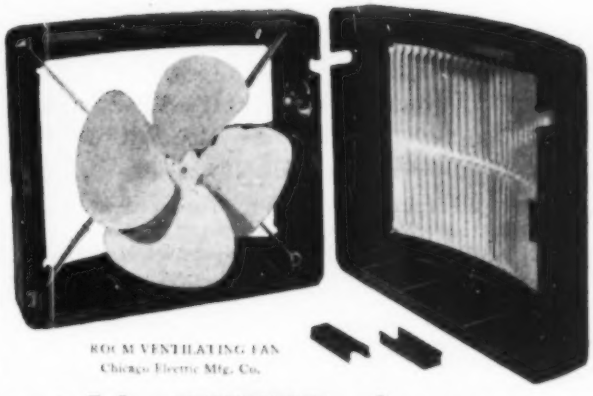
Why not think BIG when you plan on plastics?

TELEVISION CABINET
Motorola, Inc.

POPCORN WARMER BASE
Buddy Boy Popcorn Co.



HEAVY-DUTY SWITCH PANEL
I. T. E. Circuit Breaker Co.



ROOM VENTILATING FAN
Chicago Electric Mfg. Co.

...see your molder about big DUREZ pieces

If you have always limited your thinking on plastics to fairly small pieces, we invite you to consider them in a brand new light . . . as material for major units or components.

Bigger presses, improved techniques in custom molding, and the versatility of phenolics developed by Durez have greatly *enlarged* the utility of moldings in recent years.

Pieces weighing up to 40 pounds and more are now turned out, *ready for assembly*, at mass production speed. These range up to 15" x 18" x 36", and their size is determined only by the capacity of available presses. The larger the size, the greater is the economy available through elimination of many machining, assembly, and finishing operations.

In large and small moldings the inherent characteristics of Durez phenolics have won them an important place in industry. They mold to critical tolerances. They have outstanding electrical values and resistance to chemicals and to heat, plus impact strength and permanence of finish.

It will pay you to discuss your large projects with your custom molder. For specialized assistance, feel free to call on Durez technicians in your area.

Our monthly "Durez Plastics News" contains many useful ideas. May we place you on the list? Durez Plastics & Chemicals, Inc., 2004 Walck Road, North Tonawanda, New York.

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internal combustion engines severely stress the piston material, and we may deduce from the creep and fatigue curves of the sintered aluminum that the admissible working stresses under such conditions will be many times higher for sintered aluminum than for Al-alloys used at present. The higher strength of the sintered material would permit fabrication of the pistons with high-strength sintered inserts produced to the desired shape by die pressing. The blades of air compressors for gas turbines could well be made from this material and, quite generally, the existence of a heat-resistant light metal will offer new possibilities for the design of various types of machinery.

Current Limiting Circuit

Abstracted from "New Industrial Motor Control Circuits" by E. F. Kubler, *Electronics* Magazine, page 110, March, 1952.

THIS ARTICLE EXPLAINS IN DETAIL the circuit operation of an electronic d-c motor control. The type of control is used to supply rectified a-c power to the armature and field circuits of motors in the ¾ to 3 hp range. The complete control unit regulates motor speed at any value from zero to top speed under any load condition.

Thyratron tubes are the rectifiers employed for feeding the motor field and armature. To prevent damaging current from flowing through the armature rectifier tube under starting conditions or heavy loading, the current-limiting circuit of Fig. 1 has been added to the speed-regulating circuit. For efficient operation this circuit must not interfere with the motor speed when it is operating at normal load. This means that the current limit circuit must have a sharp take-over characteristic when the motor current exceeds a preset value that is selected in advance.

Voltage divider R_{30}-R_{31} compares the voltage drop across R_{19} in the current transformer circuit with a reference voltage set by potentiometer P_4. Current limit tube V_{13} is in parallel with speed control tube V_8, hence V_{13} shuts off the armature thyratrons under current limit action when it overrides V_8.

Under starting conditions the current is regulated at a preset value until the counter emf is sufficiently high to limit the current to a smaller level. With normal motor load, the grid of V_{13} is held sufficiently negative to keep this tube below cutoff, and speed regulator tube V_8 is in full control. Circuit components R_{33} and C_{12} filter the grid voltage of V_{13} and stabilize

Where you will find THE REAL REVOLUTION

"If we keep in mind the values of opportunity, competition, democracy, productivity, then it is our capitalist society which is the truly revolutionary one – the only society which offers true hope to the masses for release from the long nightmares of tyranny. It is we, not the Marxists with their reactionary ideas of the good dictator, who have the truly constructive, the truly revolutionary ideal."

– from "Capitalism" by David McCord Wright.

If we can only win recognition of this truth, we shall win the struggle of free men against communism. This editorial discusses some of the hurdles that must be cleared.

To win the needed recognition that "our capitalistic society... is the truly revolutionary one," we must keep pounding away both abroad and at home. That is because the communists simultaneously attack us on an international front and try to undermine us from within.

The present drive to rearm ourselves and our allies is crucial to our self-protection on the international front. We must be prepared to meet the armed force of aggressive communism with armed force if we are to secure our physical freedom.

Arms are not enough

But to re-establish parity in arms is only half of the battle. In the last analysis it is not the more important half. To be effective, our arms must be backed by loyalty of men to our ideals. So, both abroad and at home, we must win men to the faith that we do have "the truly constructive, the truly revolutionary ideal."

On the international front, the effort to win adherence to such faith in our capitalist society meets tough going. That arises from the fact that in some of the countries that are allied with us in the fight against communism, capitalist society has offered to its people no such ideal. In varying degrees "the values of opportunity, competition, democracy, productivity" – those key aspects of American capitalism–are either absent or subordinated in their economic life. Indeed, the *Wall Street Journal* recently remarked that "to the European, capitalism has become synonymous with cartels – and with the disregard cartels foster for the consumer, the worker and the over-all well-being of the nation's economy."

No Simple Solution

Nonetheless, many European labor and governmental leaders sincerely believe that cartels are essential to their economic salvation. They believe that without such restrictions in congested European markets there would be intolerable cut-throat competition and instability of employment. Thus, when we point out that the cartel capitalism so prevalent in Europe lacks the constructive qualities of competitive American capitalism, we may offend European leaders whose wholehearted cooperation we need in the fight against communism.

But, if we soft-pedal that contrast, we sacrifice the opportunity to win understanding and loyalty from millions of Europeans who have had no chance to learn that capitalism can be the constructive and liberalizing force that it is in the United States. Indeed, when many of these millions embrace socialism it is not because they love it. They are rather desperately seeking a tolerable middle course between what they consider the hateful extremes of communism and the undesirable aspects of capitalism as they understand it.

New name not the answer

We know that there is no easy way to handle the problems created by such misunderstanding of American capitalism. Neither do we share the belief that much of the difficulty would be overcome if we were to call American capitalism by some other name. By doing that, the argument runs, we shall relieve it from the unpleasant connotations that are attached to the word capitalism in some other parts of the world. But, after all, if we are to give up all the terms that have come to mean something else in other parts of the world, we must begin by ditching the term "democracy" which, in the official jargon of the Kremlin, seems to mean what we call dictatorship.

In spite of the difficulties, however, we must stick to this job of exporting the truth that our capitalist system does offer opportunity, competition and democracy. We must let the rest of the world see that it means a continuous drive for increased productivity, and the search for profits by increasing sales and consumption, not by trying to sell less for more.

Export alone not enough

The spreading of truth about American capitalism will not be effective if it is merely directed abroad. Unless it is carried on at home also, it will lack the driving faith that is essential to any convincing export of this type. Nor will export alone come to grips with the communist attack on our country from within—an attack that gets too much help from loyal Americans who short-sightedly repudiate the basic principles of our institutions in their efforts to reform some of their deficiencies. For success both at home and abroad, we must have right here at home a much more militant recognition that it is in fact our capitalist society which offers "the truly constructive, the truly revolutionary ideal."

Here at home, too, this raises difficult complications. Businessmen who are among the leaders and principal practitioners of capitalism, have generally been catalogued as conservatives. Hence, many people must stretch their imaginations a bit to see that businessmen are leaders of a development which has so greatly and so rapidly improved the lot of free men in America that it is truly revolutionary.

These difficulties of definition, however, are relatively superficial aspects of the problem of seeing our capitalist society clearly. The basic facts are that:

American capitalism is leading free men to an ever higher material standard of living while respecting their spiritual, social and political freedom.

Communism is leading its people back into a life of servile regimentation under dictatorship.

American capitalism advances to high ground never before attained by free men. Communism retreats to ground that men with an appetite for freedom throughout the ages have sought to escape. If we can establish this truth firmly, around the world, we shall no longer need to worry about communism. It will be hopelessly sunk.

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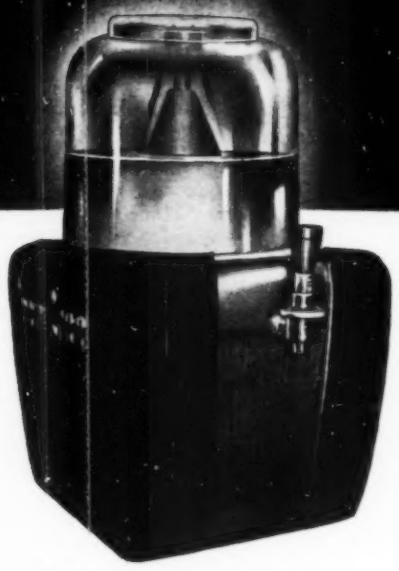

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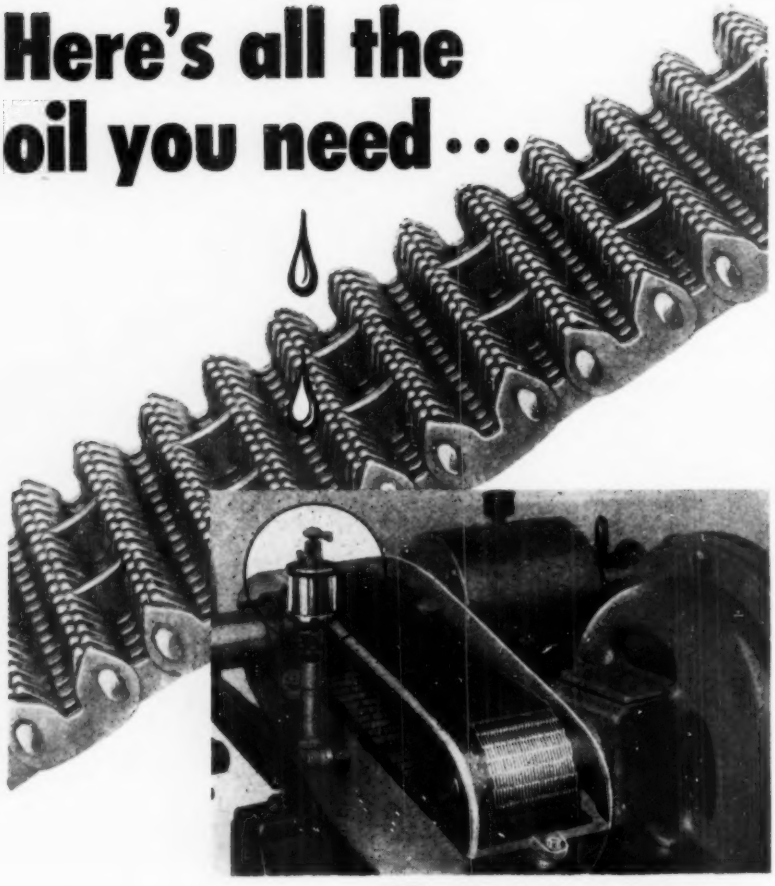

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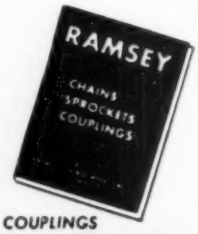

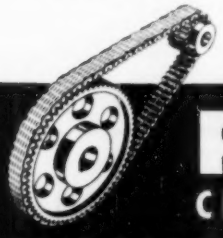

SILENT CHAIN DRIVES – FLEXIBLE COUPLINGS

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the operation of the current limit circuit.

Since the motor voltage is measured on the rectifier side of normally-closed contactor M, the speed-regulating circuit will hold the rectifier voltage at the value called for by speed reference potentiometer P_1 when the motor is disconnected from the rectifier. If the motor were started with P_1 set above base speed, the full rectifier voltage would be applied to the motor at the moment the contactor closes. Unfortunately the current limit circuit cannot operate instantaneously because the grid of V_{13} is held negative by P_4 when contactor M is open and C_{12} will prevent the grid of V_{13} from reaching the operating range instantly. This condition cannot be tolerated because currents of destructive magnitude would flow for the first instant after the motor is started, resulting in blown anode fuses. To remedy this condition the rectifier voltage is automatically regulated to a lower voltage when contactor M is open, by means of the preconditioning circuit.

Preconditioning Circuit

This circuit regulates the open-circuit rectifier voltage to a permissible value and provides good starting torque without harmful effects.

A part of the armature rectifier voltage, obtained from R_{34} and R_{35} is fed back to the grid of V_{13} through R_{52} and a normally-closed interlock of the main contactor M. When contactor M is deenergized the voltage across R_{35} is compared with the reference

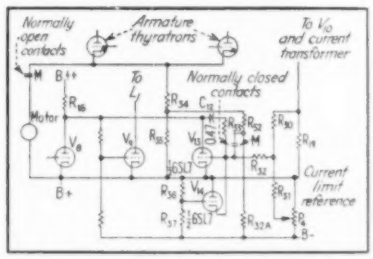

FIG. 1 — Diagram of current limiting circuit.

voltage provided by a glow tube by means of resistance divider R_{52} and R_{32A}. These resistors are chosen so that a precondition voltage of 20 to 70 v is obtained, depending on the horsepower rating of the motor. This particular resistance network is stiff enough to prevent any interference from the current limit reference.

A similar situation may occur when the speed is suddenly increased. If the motor is operating at light load, the grid of V_{13} is held very negative by virtue of current limit reference P_4,

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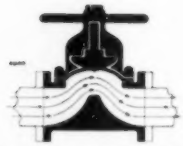
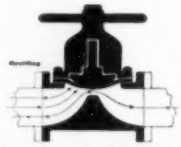
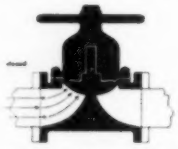


Compressor is raised, lifting diaphragm by means of a stud molded into the material.



Compressor and diaphragm partially lowered. Compressor design guides and supports diaphragm.



Compressor presses diaphragm tightly against weir, pinching off flow and making a tight seal.

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consequently C_{12} has a negative charge. If the speed potentiometer is suddenly turned to a higher speed a large instantaneous current flows because C_{12} prevents the grid of V_{13} from reaching the operating range immediately. Tube V_{14} prevents the grid of V_{13} from drifting too far below its operating range. The grid of V_{14} is held approximately 10 v below its plate by R_{36} and R_{37}. Since the cathode of V_{14} cannot exceed this voltage, the grid of V_{13} is also held approximately 10 v negative; this 10 v negative bias prevents V_{13} from interfering with the normal operation of V_8.

Design of Gray-Iron Castings

Abstracted from "Design of Gray-Iron Castings" by T. E. Eagan, *Iron Age*, February 7, 1952

A CASTING will be no better than its design allows the foundry to make it. There are more gray-iron castings which have been overdesigned than there are which have been properly designed. This is due mainly to the fact that designers have not been cognizant of the characteristics of the modern gray irons and, therefore, have not used them properly. Hence it is recommended that the designers become more familiar with the engineering properties of gray iron and use them to the best advantage.

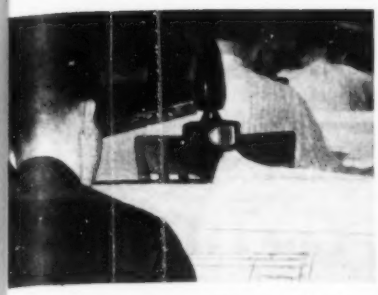
Modern foundry practice requires that the art of molding be changed to the science of molding in order efficiently and economically to produce castings. However, there are numerous foundrymen still at work who are willing to tackle any job. Therefore it becomes a matter of necessity that designers take heed of this condition and know the foundry and foundrymen with whom he is dealing.

Conversely, the designer should be willing to change his design to conform to good foundry practice so long as its intended functional qualities are not impaired. The very fact that the designer willingly consults with the foundryman precludes much trouble in this respect.

Some of the things which should be checked with the foundryman are as follows:

1 General designing of the casting.
2. How the casting is to be molded.
3 Location of the parting line.
4 Accessibility for any enclosed spaces for cleaning.
5 Dimensional limits that must be held.

In cases where a great number of castings of one design are to be made,



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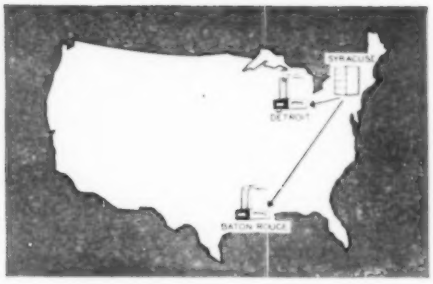

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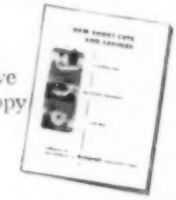

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or where a considerable expense is involved in making the patters, or where the design is very intricate, it is advisable to have a scale or full-size model made. By doing this many troubles which could be foreseen by no other method can be avoided.

Castings should have sections which are no thicker than necessary to meet the required stress imposed on them. This is logical because the physical properties obtained are based upon the section thickness. On the other hand, the section thickness must not be so thin that the metal will not run through it. This latter condition can best be set by the foundryman who must gate the casting to allow the proper flow of metal.

All sharp angles should be avoided. Use gentle contours wherever possible. Proper radii should be used in all cases. Too-large a radius is just as bad as a too-small one. In order to avoid stress concentration, the fillet radius of $\frac{1}{3}$ or $\frac{1}{2}$ the thickness is better for soundness in the castings. Therefore some compromise usually must be made with the foundry-man.

Design castings with a uniform section thickness. Where this is impossible blend the sections together instead of making abrupt connections. However, because the inner walls cool more slowly than the outer walls, they should be 0.7 to 0.9 of the outer-wall thickness, depending upon the intricacy of the pattern.

Always reconsider large complicated castings to see if the same results could be obtained by joining several less complicated sections together.

Ribs should be employed, but only where they will help in reducing the weight or warpage of the casting. Sometimes ribs can be culminated entirely by designing a bulge in the section instead of a rib. They are effective in compression, but not so in tension. There is a tendency for designers to add more ribs than necessary to a casting. Many of these do not function, yet they add to the cost and, in many cases, interfere with proper molding, often leading to a greater number of rejects.

The amount of machine finish allowance varies with the analysis of the metal used, the design of the casting, and its size, the tendency to warp, and the machining methods used. In the case of cylinders, special allowances must be made, and the foundry should be contacted to determine these.

It is desirable that an agreement be made with the producing foundry on the machining allowances required. Then these allowances should be indicated on the drawing. This acts as a guide to the foundryman for the choice

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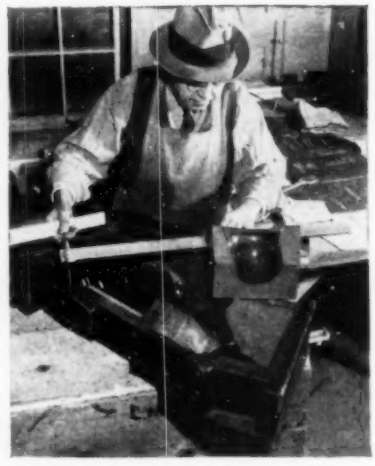

Lebanon Steel Foundry pattern makers study engineering designs, suggest improvements and plan jobs for production giving careful consideration to feed heads, rigging and gating. This care in preparation can save valuable time and eliminate costly failures. Pattern making, however, is but one of many steps in production rigidly followed by Lebanon craftsmen to provide CIRCLE (L) castings of *controlled* high quality.

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CIRCLE L LEBANON *Steel and Alloy Steel* Castings

of pattern needs repair or replacement. In large castings many foundrymen may use certain surfaces as dirt traps which require rather heavy finish allowances. It should be determined if such practice can be tolerated economically.

A great many castings are made with machine reference or locating pads which are usually ground to the proper dimensions by the foundry. These, of course, should be marked clearly on the drawing, and the dimension limits clearly indicated.

Permanent-mold and castings made by other specialized casting processes, require special machining allowances. As these usually have particular requirements, the foundry which is going to make the castings should be contacted.

Treatment for Internal Stresses

Most gray-iron castings have some internal stresses in them which may cause warping during machining. The higher-strength irons usually have the highest internal stress. Unless these stresses are deliberately put into the casting for strength-anneal.

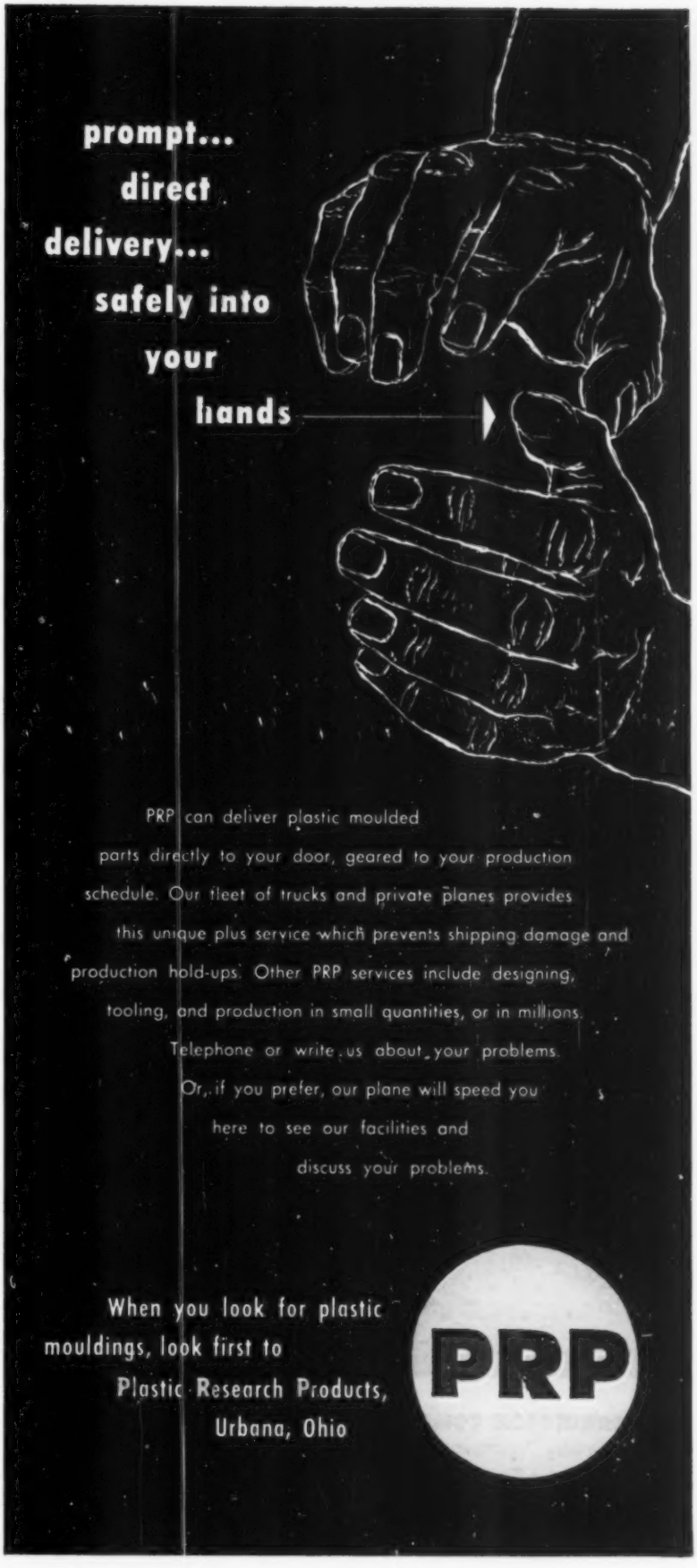
It is not sufficient to call for a stress-relief anneal, because there are many erroneous ideas as to what constitutes a proper stress-relief-annealing treatment. On this subject no standard of recommended practices has been issued by the various technical societies. Therefore it is necessary that the annealing cycle be indicated either by a special specification or noted on the drawing. As a guide the following rules are used by the author's company:

1 Heat castings slowly and evenly at a rate not to exceed 50 F per hr to 1050 F.

2 Hold at 1050 F for 1 hr per in. of heaviest section.

3 Cool at a rate of not more than 400 F per hr until a temperature of 500 F is reached, then air-cool.

It is well to discuss briefly some of the erroneous ideas about stress-relieving gray iron. Schaum has shown that no relief of stress occurs in castings by storing them for 1½ years outdoors, yet this practice is still used. Alternate heating to 220 F and then cooling to 0 F does not remove stress. Etching the surface shows a small amount of stress-relief but not enough to be of any consequence. Schaum also has shown that it takes many hours to relieve stresses at temperatures below 950 F, yet some foundries use temperatures as low as 500 F. The way to relieve stress is to follow similar procedure to that recommended in the foregoing.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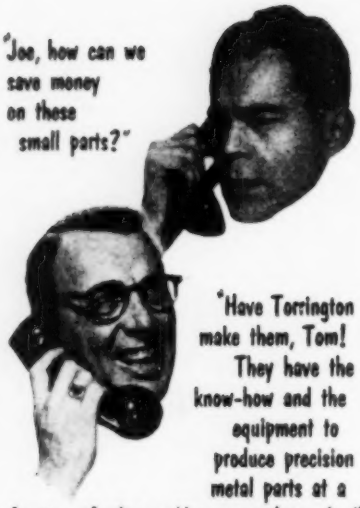
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OUR READERS SAY

Correct German Address

To the Editor:

In the article "Diesel Engine Cooled by Forced Air", page 150 of the January issue, the address of the manufacturer is incorrect. The location of the Kloeckner-Humboldt-Deutz A. G. is Cologne, Germany. The designation "Cologne, Rhine" is incorrect and any inquiries that your readers may send to the Deutz Factory, addressed that way, will most probably be returned by the post office.

The Diesel Energy Corporation at 47 West Street, New York 6, N. Y. is the sole representative of Kloeckner-Humboldt-Deutz in the United States. Inquiries can be addressed to this organization for prompt handling.

H. W. RATHENAU
Diesel Energy Corp.

Ed—Our German Boedeker missed on that one. You'll find the address corrected in the Errata section at the end of our Readers Say Department.

Gears for Instrument Drives

To the Editor:

I read with interest the article "Optimum Selection of Gears for Precision Instrument Drives" in the January 1952 issue of PRODUCT ENGINEERING.

The first thing that caught my eye was the diagram of the gear-hobbing machine with the dual-lead worm and gear. Apparently it is a composite diagram of B-C and G&E machines. The explanation of dual-lead worm gearing and proper design of accurate instrument worm gearing are well handled.

One serious error appears in the opening paragraph on p. 167, referring to the matching of one to one bevel gears, wherein the author advocates matching the high point of runout of one gear with the low point of runout of its mate. This is just the opposite of what one should do, if interested in the accurate transmission of motion. Such gears should be mounted so that the two high points are in mesh, and the two low points in mesh. This will admittedly cause changes in backlash in the train; however, the article stresses accuracy of

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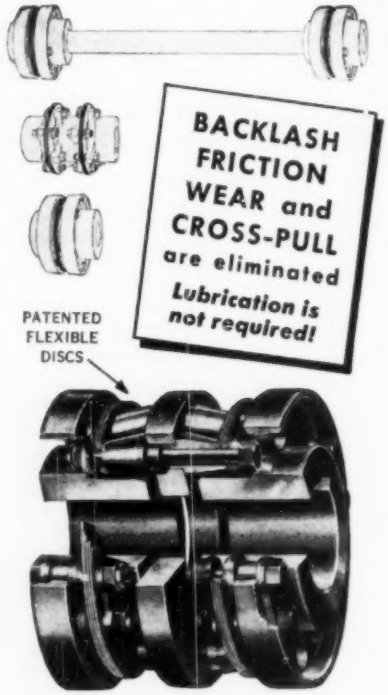

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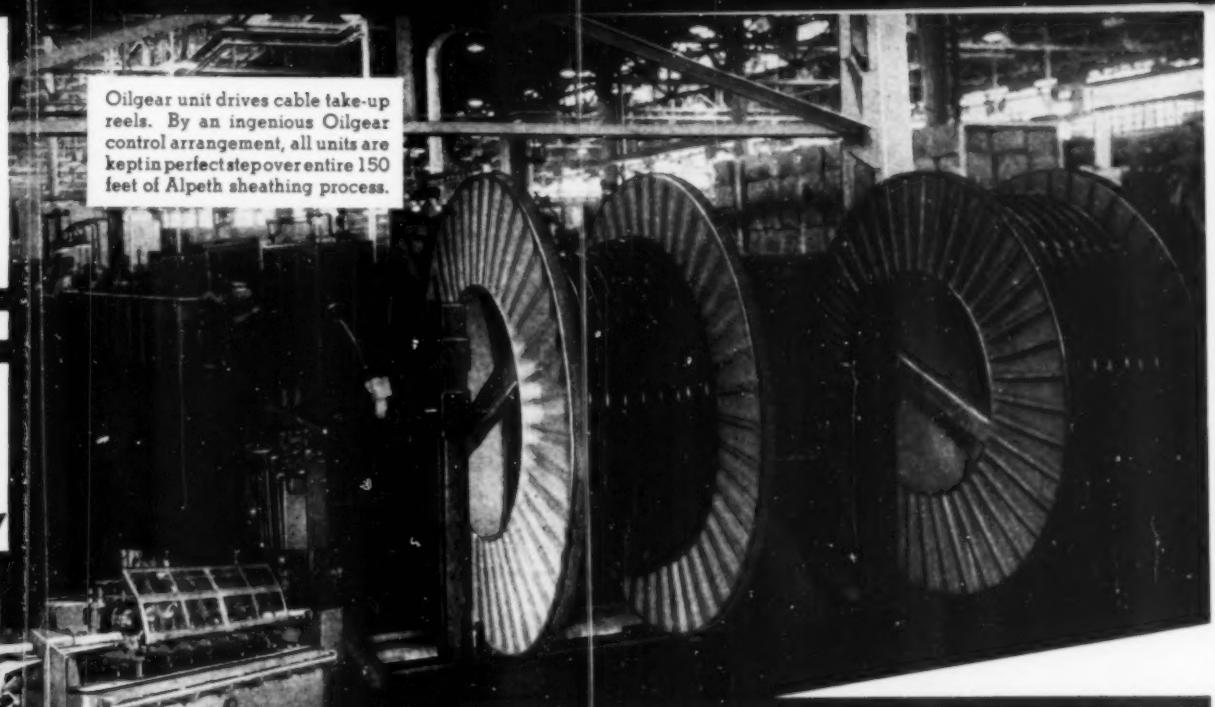

Oilgear unit drives cable take-up reels. By an ingenious Oilgear control arrangement, all units are kept in perfect step over entire 150 feet of Alpeth sheathing process.

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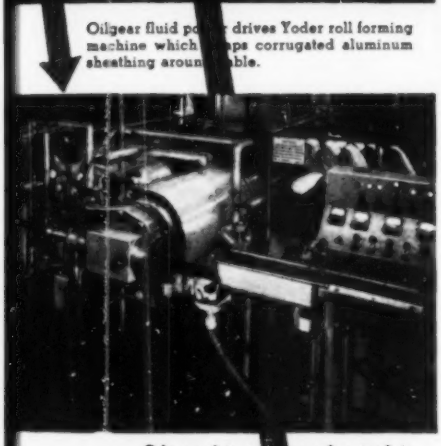

Oilgear fluid po[wer] drives Yoder roll forming machine which [forms] corrugated aluminum sheathing aroun[d] cable.

Oilgear drives [] synchronized to speed of Royle e[xtr]uder which covers cable with melte[d] polyethylene.

Tractor capstan powered by Oilgear, which pulls cable through extruder, long cooling trough and inspection station.

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motion transmission, rather than minimum backlash.

In further explanation of why one to one gears should always be assembled with their two high points together, suppose we consider two spur gears of one to one ratio meshed together with their high points of runout in line. Then alongside of these spur gears assume that there are two pitch disks of equal size, mounted perfectly concentrically with their shafts. If we sight along through the spur teeth on their driving sides, and transfer marks onto the periphery of each disk, and then measure the spacing of the marks, we observe that the spacing near the high point of runout of the gears is closer than the spacing 180 deg around where the gears mesh at their low point. This change in spacing is equivalent to a change of pitch of the eccentric gears, where pitch is defined as the distance from one tooth to the corresponding point of the next, along a true running pitch disk. Obviously this effective change of pitch is not harmful provided it is the same on both gears, and if the gears are properly meshed. Also, for best results, both gears should runout an equal amount. On the other hand, if one of the two gears is turned 180 deg with respect to the other, the differences in effective pitch between the pair will cause an acceleration and deceleration of the driven gear for each revolution.

—GEORGE DAVIS

Author's Comment—

Mr. Davis is right in saying that the angular transmission is aggravated when the high and low spots of gears of one to one ratio are matched. It is certainly better to match the high or low spots if angular transmission is the only consideration. When this is done, of course, backlash is worsened.

From the observation of thousands of traces of composite checks of gears, one seldom, if ever, sees a true sinusoidal type of chart over which tooth-to-tooth errors are superimposed. Generally, the sine wave is distorted by the conglomeration of other errors superimposed on it.

It is common practice to lap miter bevel gears in pairs. When this procedure is followed, the high spot is matched with the low spot. Sometimes the teeth are oriented one to the other to get the best feel of roll. After the gears are properly lapped, the engaging teeth are marked at some point so that in assembly the same teeth mesh each other.

In the article, I pointed out that a gear train in which a worm drive is

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used, accuracy should be concentrated on the worm and gear. It was stated that worm gearing act as mechanical filters, and that angular errors in the gearing leading to the worms was not as important as those in the worm gearing itself. Backlash control in many instruments is quite often a major factor, because it affects the ease of reading scales or dials. In the gear train shown in the article in which miters were substituted for uneven ratio bevels, the idea was to focus attention to (*a*) economy; (*b*) backlash-elimination when desirable, although as Mr. Davis points out at some sacrifice in angular motion; (*c*) the fact that low lead angle worms should be used; and (*d*) that when this accuracy is concentrated at the key points, such as at worms and screws, the gearing leading to these points can have much broader tolerance.

To focus attention to this concept, a well-known hobbing machine gear train was shown with the several key points marked. It does not employ a dual lead worm. The dual lead worm was shown as an argument for avoiding split worms to take up backlash. By means of dual lead worms, it is possible to obtain backlash control without affecting conjugate action. The particular dual lead worm shown in the article was used in a very special machine. To the best of my knowledge, the Gould and Eberhart hobbing machines are the only ones employing dual lead worms, although they have been used elsewhere under licenses from the owners of patent rights.

I am indebted to Mr. Davis for his constructive comments, and for the opportunity to amplify my statements regarding miter gears.

—L. M. DAVISON

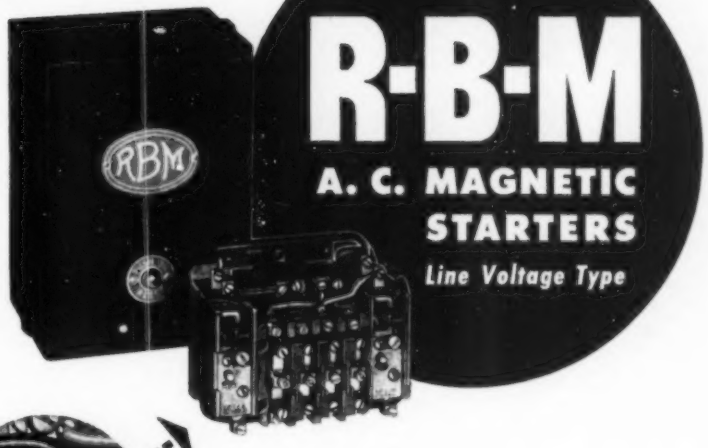
From a Polish Student

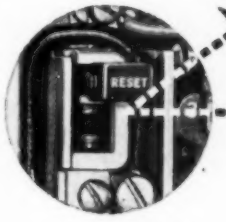
To the Editor:

I am a student of the Electromechanical Faculty of the Mining Academy in Krakow and am preparing diploma work on "The Application of the Grid-Controlled Rectifiers to a Rolling Mill Installation."

I would like to get information concerning this problem that has appeared in American technical literature, books and newspapers. I am interested in the general scheme of the rectifier installation in application to rolling mill drives, its parts and operation; comparison between the rectifier installation and motor-generator set installation with regard to: maneuverability, starting, speed variation, braking and reversing; efficiency

NEW!





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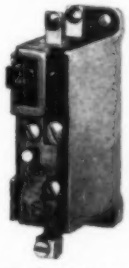

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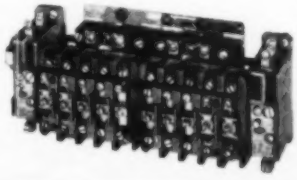

Two 5 pole contactors mechanically interlocked with overload protection on common base. Unwired. Note interchangeability of 25 ampere N.O. contacts and 15 ampere convertible N.O. or N.C. interlocks.

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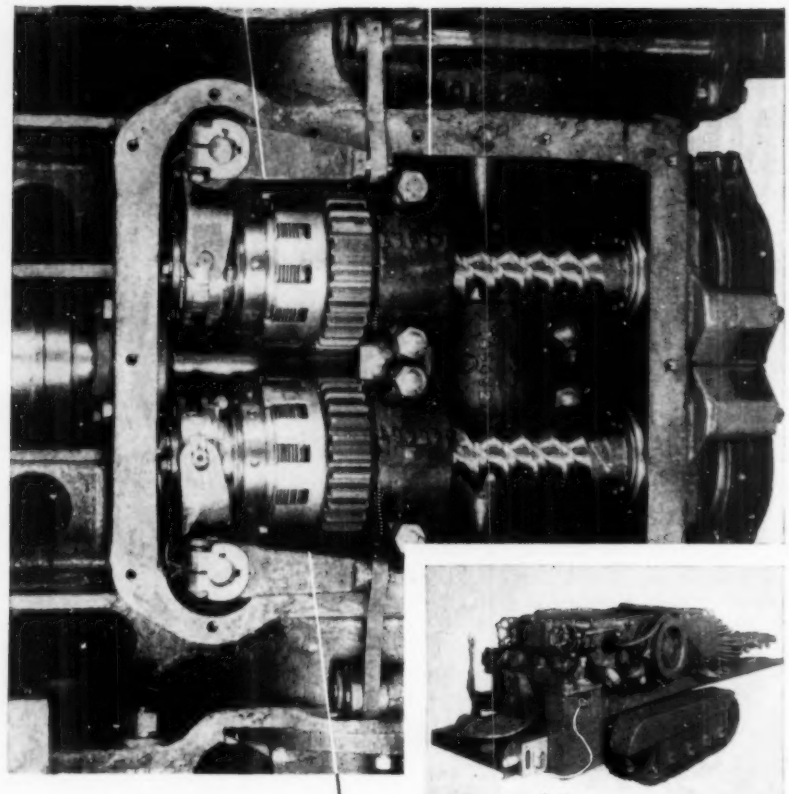

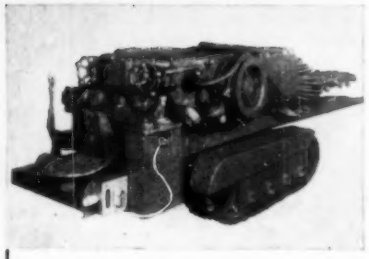

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and power consumption per ton rolled; installation and maintenance costs; utilization of the flywheel energy; rolling speed and maximum possible tonnage output from the mill; and influence on the power factor.

—HAJNOS FRANCISZEK
Krakow, Skrytka pocztowa 235
Poland

Ed—Sorry, but information on grid-controlled rectifiers for rolling mills is a little out of our field of interest. We suggest you try some of our magazines that are directly concerned with the iron and steel industry.

Computer Mixup

To the Editor:

The article, "Organizing a Computing Center in the Engineering Department," which appeared in the January issue of PRODUCT ENGINEERING contained a confusing reference which should be cleared up.

In the article and in a photo caption the IBM Selective Sequence Electronic Calculator was referred to parenthetically as the "Defense Calculator." Actually, they are two separate and distinctly different machines. The SSEC was put into service in January of 1948. The Defense Calculator is an advanced development currently under way in our engineering laboratories. —H. T. ROWE
International Business Machines Corp.

Ed—PE apologizes for the confusion. The Defense Calculator was announced during the preparation of this article and it's description as a "selective sequence electronic computer" tripped PE editors into mistaking the IBM Selective Sequence Electronic Calculator for the new machine.

Suggestions for Cutting Ball Bearing Vibration

To the Editor:

In his article "Noise and Vibration in Ball Bearings" (PRODUCT ENGINEERING, December 1951, pp. 150 et seq.), Mr. George H. Kendall investigates the different sources of vibration and noise in ball bearing assemblies. After discussing the influence of misalignment of ball bearing races, loose clearance of balls, and damaged race ways, end shields or ball retainers, he turns to the influence of improper shoulders confining the races, especially flat retaining rings with a possible end play of from 0.005 to 0.0170 in.

As Mr. Kendall states, this end play

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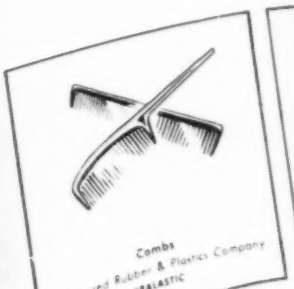

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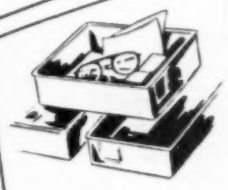

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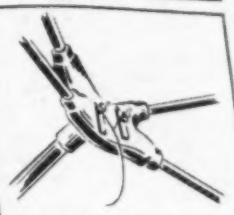

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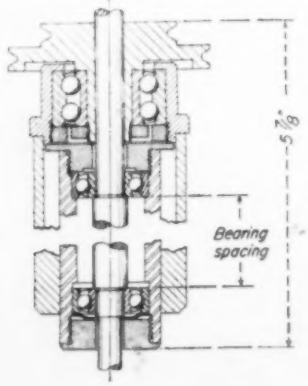
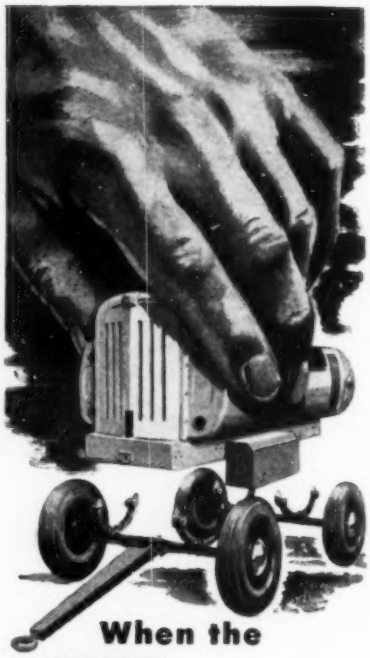
is the result of the assembly of components which are "at the extremes of their dimensional tolerances". From this one has to conclude that the often proposed precision grinding of retaining rings does not solve this problem because the tolerance of ring thickness is only one part of possible end play and not even the principal part. The main part of end play equals the maximum variation of length of machine part plus maximum variation of distance of outer groove wall from the inner abutting shoulder of shaft or housing.

To solve this problem of end play in retaining ring assemblies, Waldes Ohinoor, Inc. has developed the Waldes Truarc Beveled retaining ring. The groove-engaging edge of this ring is tapered or beveled under a small angle (about 15 deg) and abuts against an outer groove wall that is tapered at the same angle. With a load on the ring, the tapered edge acts like a wedge so that the ring, expanding or contracting more deeply into the groove, is shifted to a certain degree in the axial direction until it abuts against the machine part, thus bridging end play rigidly.

For smaller sizes of shaft or housing (under 1 in.), the maximal possible take-up of such a beveled ring in a beveled groove is not large enough for the maximal possible sum of tolerances in length of machine part, groove location, and ring thickness. On the other hand, in such smaller ring assemblies, the axially directed forces of thrusts, impacts, or vibrations are relatively moderate. To deal with end play in these cases, the Waldes Truarc Bowed retaining ring was introduced. This ring is bent out of its plane around its horizontal center line and acts as a floating spring taking up end play resiliently and damping vibrations (cp. the article "Which Stamped Retaining Ring?" in PRODUCT ENGINEERING of February 1950, pp. 124 et seq.).

Both Waldes Truarc Beveled and





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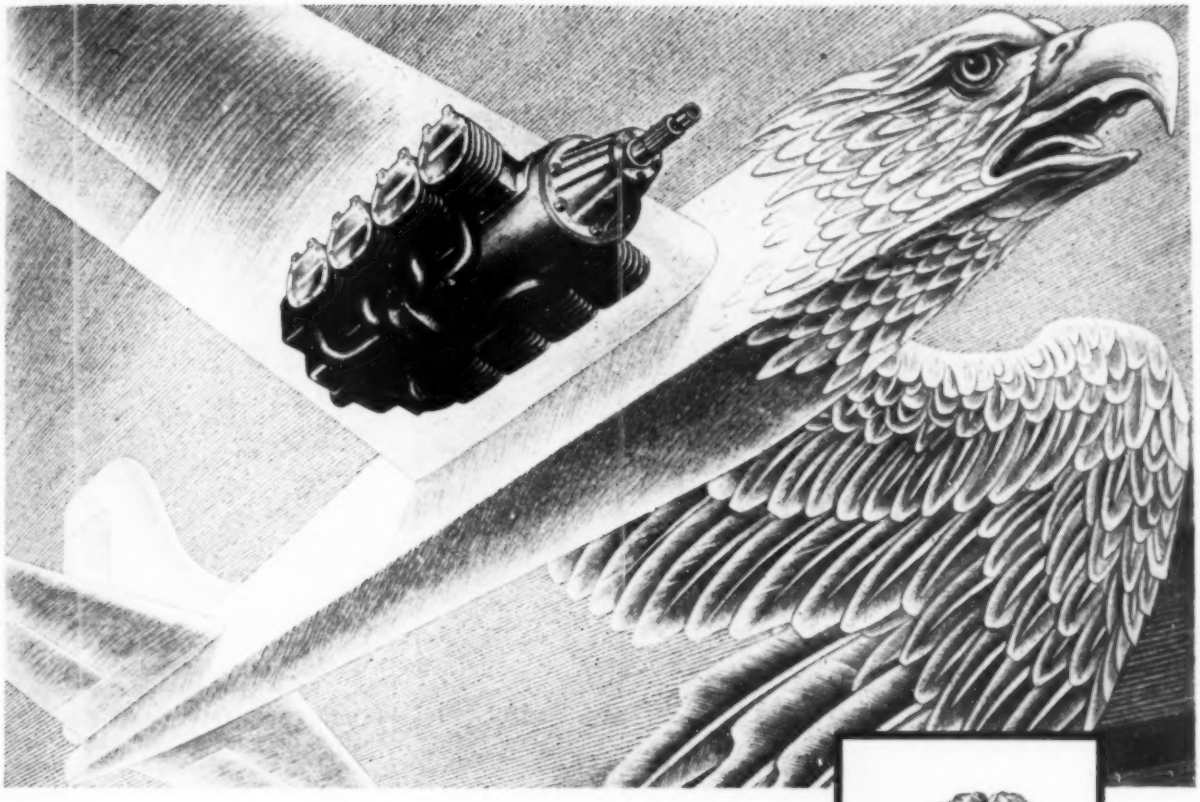

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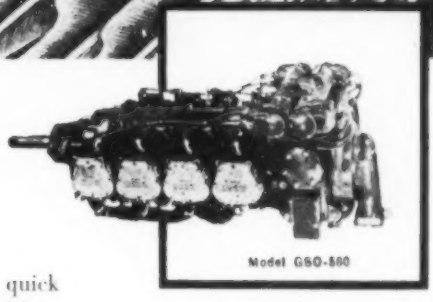

A versatile aircraft engine with reserve power for quick take-offs, military hedge-hopping, more lift! *Geared* for smoother operation; "*opposed*" *design* for practical compactness; *supercharged* for greater power; the only 400-horsepower air-cooled engine being produced! That's the unique power plant now available through Lycoming research and precision production.

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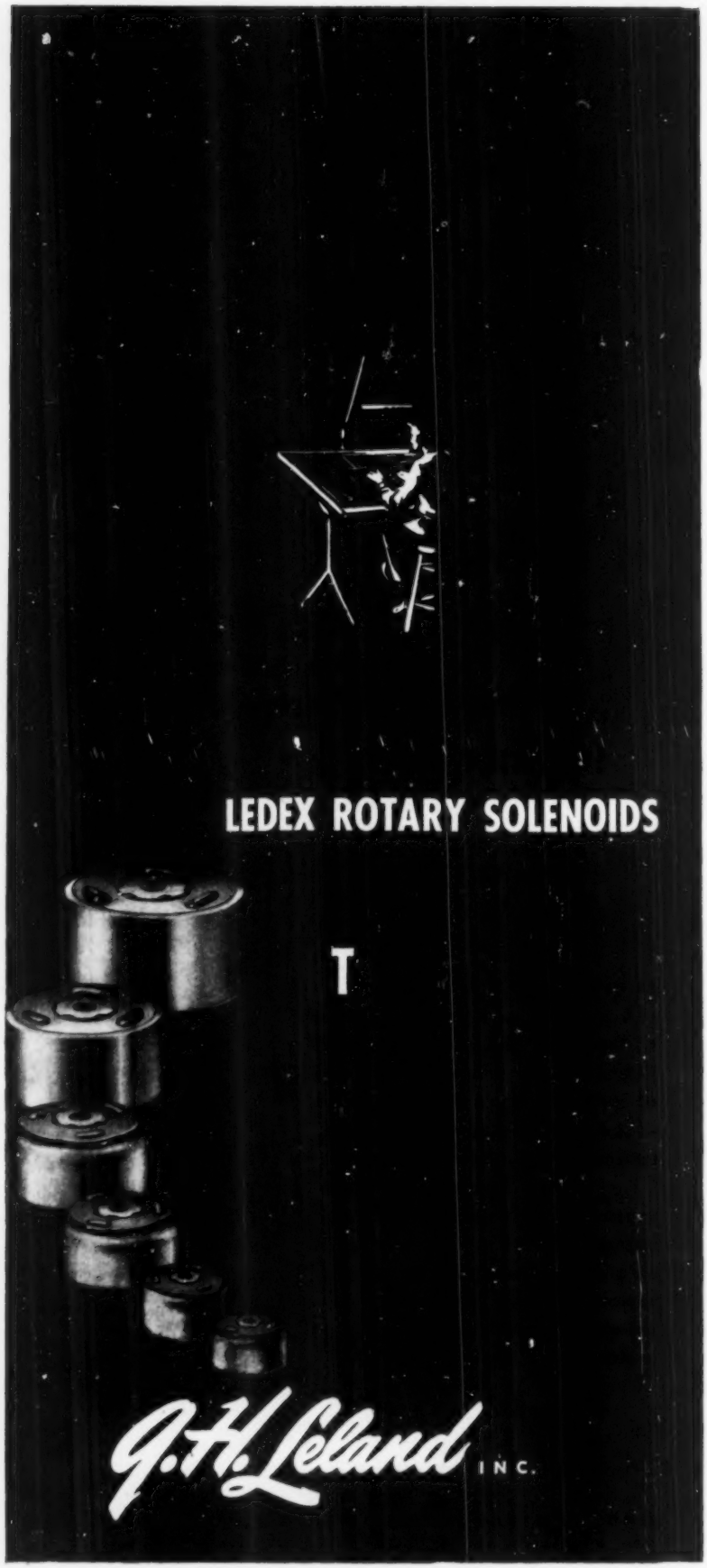
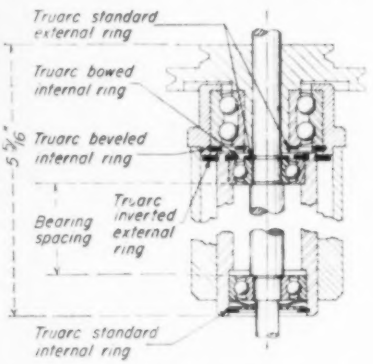


Bowed retaining rings have been successfully applied in many cases of machine assemblies with high rotational speed. Fig. 1 and 2 show, as one among many examples, a drill press spindle arrangement. Fig. 1 the



old way, Fig. 2 the new way. For locating the outer race of the main ball bearing there is an internal Waldes Truarc Beveled ring applied in a correspondingly beveled groove. Furthermore, for locating the outer race of the spindle bearing, an internal Waldes Truarc Bowed ring is employed. Both rings eliminated the end play which otherwise would be unavoidable.

Further information about Waldes Truarc Bowed and Beveled retaining rings is available in our Bulletin No. 6.

—H. HEINMANN
Waldes Kohinoor, Inc.

Ed—Space requirements made it necessary to separate the above figures. However it is interesting to note that the bearing space is the same in both methods.

Reprint Permission

To the Editor:

I am writing an article on plastic printing plates and would like permission to use the table included in the article "New Rubber-Phenolic Materials for Greater Impact Strength" which appeared in the January 1951 issue of PRODUCT ENGINEERING.

—AXEL LUNDBYE
Kable Printing Co.

Ed—We're pleased to grant this permission. We would appreciate a credit line to PRODUCT ENGINEERING for this material.

Polyisobutylene Adhesives

To the Editor:

I wonder if you could give me some information regarding the polyisobutylene adhesive that was mentioned

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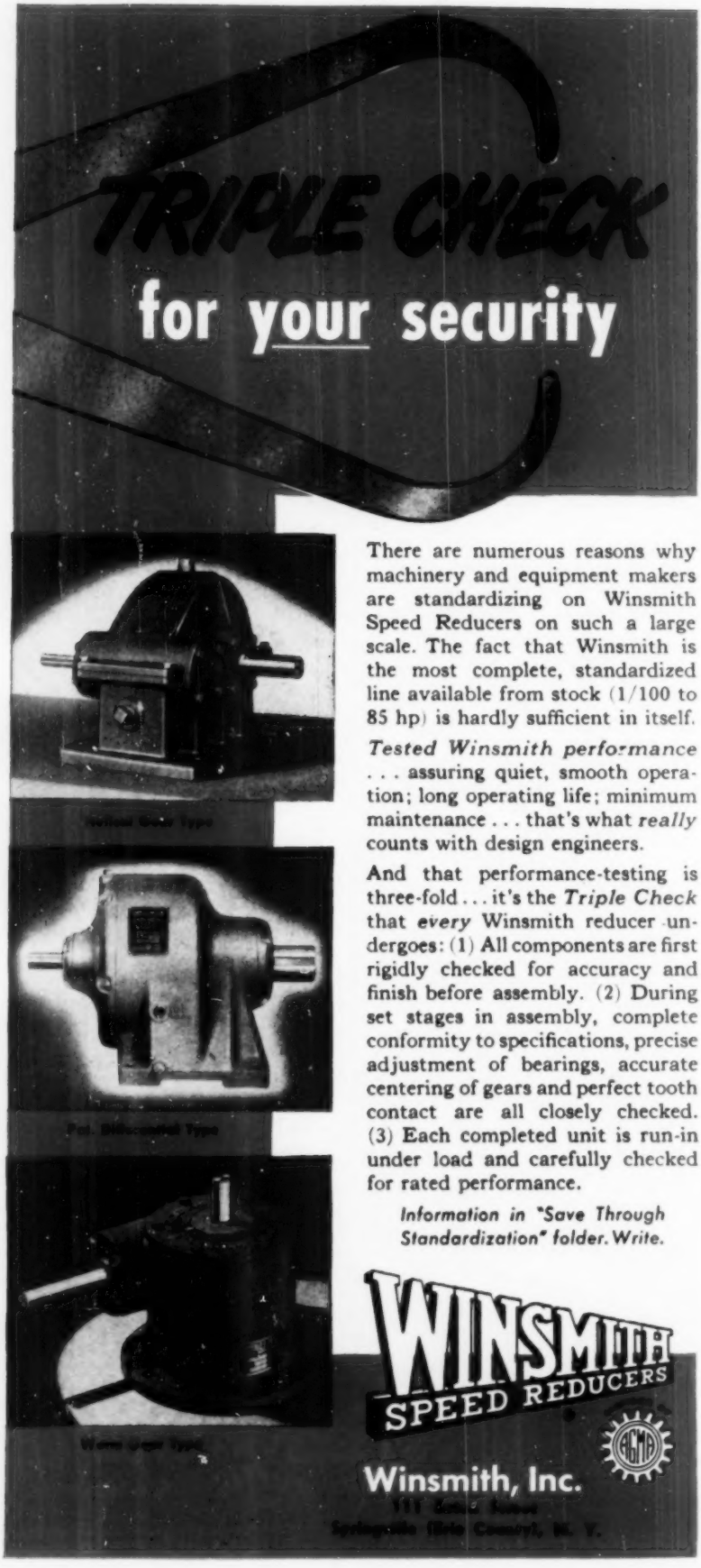
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There are numerous reasons why machinery and equipment makers are standardizing on Winsmith Speed Reducers on such a large scale. The fact that Winsmith is the most complete, standardized line available from stock (1/100 to 85 hp) is hardly sufficient in itself.
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Information in "Save Through Standardization" folder. Write.
WINSMITH
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on page 122 of your May 1951 issue. Can this type of adhesive be used to cement Teflon to Steel? What is the maximum service temperature of this adhesive? Where can it be purchased in the San Francisco bay area, or more specifically, where in San Jose?

WILLIAM A. GRAY
Owens-Corning Fiberglas Corp.

Ed—The polyisobutylene adhesive in question cannot be used to cement Teflon to steel. According to information we have, there is no adhesive that will give a good mechanical bond on Teflon. The maximum service temperature for this adhesive is 150 F. As to the procurement of the special adhesive, we can't give you the address of a specific supplier in the area you mentioned but we suggest that you get in touch with the Standard Oil Co. of California. Also the Advance Solvents and Chemical Corp., Coles and 18th Street, Jersey City, New Jersey, are suppliers of some of the basic materials used in this adhesive.

ERRATA

Oct., 1951 Page 126. *How to Tackle Materials Substitution.* The statement ". . . for example, the specifications on low temperature impact properties of armor plate for the tank program requires the use of steels with nickel content of four- to five-hundred percent greater than during the last war. . ." is incorrect. Low alloy steel compositions developed for armor during World War II are being used today with few modifications.

Dec., 1951 Page 222. *Laminated Washer of Metal and Neoprene.* Sentence ". . . Neoprene composition ranges in thickness from 1/16 in. to $\frac{1}{4}$ in., as specified. . ." should read ". . . Neoprene composition ranges in thickness from 1/16 in. to $\frac{1}{4}$ in., as specified. . ."

Feb., 1952 Page 242. *Surface Temperatures Accurately Checked.* The Phaostron Company was incorrectly listed as the supplier of this thermometer. Correct supplier is the Pacific Transducer Company, 11921 West Pico Blvd, Los Angeles 64, California.

Jan., 1952 Page 150. *Diesel Engine Cooled by Forced Air.* Cologne, Rhine is an incorrect address for Kloeckner-Humboldt Deutz A. G. The correct address is Cologne, Germany. Inquiries may be sent in the United States to the Diesel Energy Corporation, 47 West Street, New York 6, New York.

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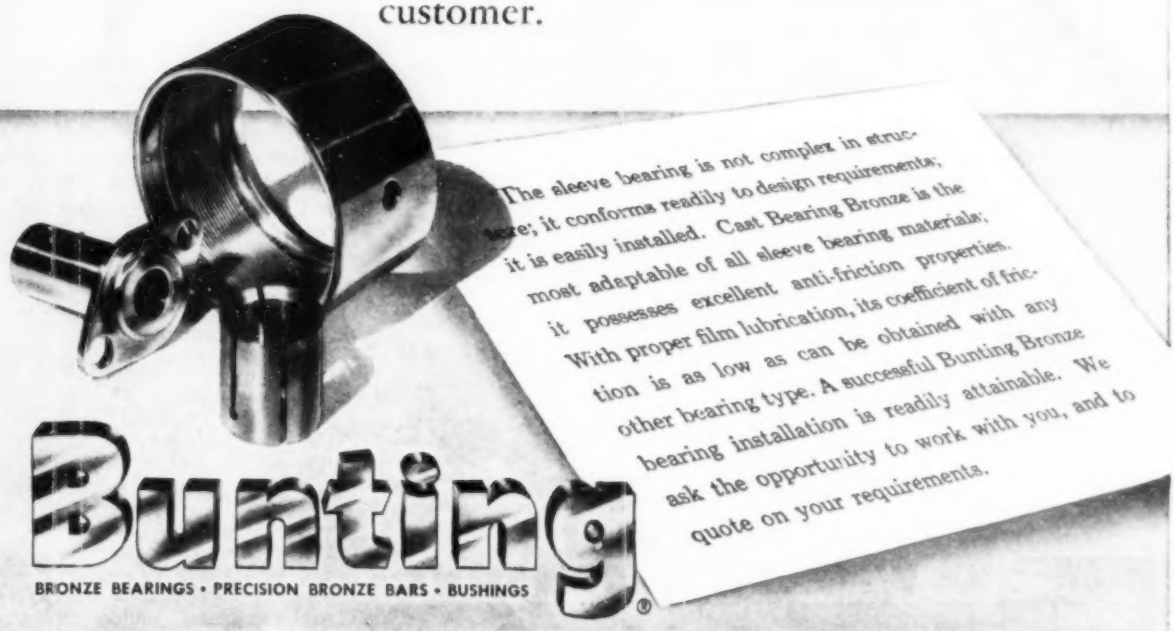
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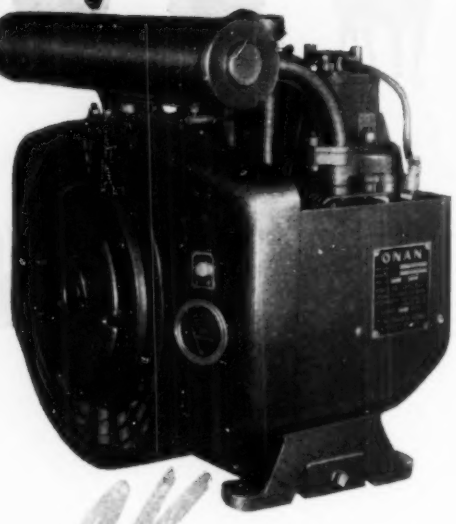

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NEW BOOKS

Production Control

PAUL D. O'DONNELL, *assistant professor of industrial management, Boston College.* 304 *pp.* 5½ x 8¼ *in. Published by Prentice-Hall, Inc., 70 Fifth Ave., New York* 11, *N. Y.*, $6.65

A basic text for those who desire to acquire an elementary knowledge of production control. The content has been simplified as much as possible; highly technical and specialized applications within the area of production control are purposely omitted. The subject matter is thus limited to enable the reader to master the fundamentals without being confused by the distractions of advanced problems.

The discussion is based upon the idea that there is no standard production control procedure. The author's premise is that there is a correct production control procedure for each company depending on whether it is a continuous process company, a job company, or some combination of the two; the size of the company; the product being manufactured; and the capabilities of the people in the company.

General consideration is given to the various phases of production control, which are applied to continuous process companies and to job companies. To indicate the effect of special factors that determine the correct procedure, cases are included to show the procedures and problems of various companies.

Included in the content of the book are chapters devoted to: Production forecasting, product development, plant layout, materials handling, control of materials, routing, scheduling, dispatching, follow-up, quality control, statistical quality control, and cost control.

Buckling Strength of Metal Structures

FRIEDRICH BLEICH, *Consulting Engineer, with* COMMANDER LYLE B. RAMSEY, *USN; edited by* HANS H. BLEICH *Associate Professor of Civil Engineering, Columbia University.* 498 *pages.* 6 x 9 *in. Published by McGraw-Hill Book Co., 330 W. 42nd St., New York* 36, *N. Y.* $10.

An urgent need for dependable data on the behavior of fabricated steel structures under compression loading prompted the preparation of

this book. Intended for use by researcher workers, and engineers actually at work on the design of steel structures and ships, it is an advanced text that includes considerable original work never before published.

Buckling problems present an entirely new aspect—the investigation of the potential unstable equilibrium between the external loading and the internal response of the structure. In addition, the buckling phenomenon in general is controlled by the entire complex stress-strain relationship of the material under consideration.

Problems associated with columns are presented in four chapters: Buckling of centrally or eccentrically loaded columns; Buckling of centrally loaded columns by torsion and flexture; Built-up columns and columns of variable stiffness; and Local buckling of plate elements of columns.

Structure stability is covered by chapters on the mathematical treatment of stability problems and the stability criteria; the Stability of frameworks; and the Stability of axially compressed bars elastically supported at specific points. Another chapter deals with the stability of web plates of girders.

Special problems in the design of ship plating conclude the text.

Throughout its contents, the book presents useful methods of analysis based on study of all available data on the subjects. It is complete with applicable methods, formulas, tables and graphs. Some simplified approximate formulas have been prepared and are presented in print for the first time.

Principles of Quantum Mechanics

WILLIAM V. HOUSTON, *The Rice Institute. International Series in Pure and Applied Physics.* 363 *pp.* 6 x 9 *in. Published by McGraw-Hill Book Co., Inc.,* 330 *W.* 42 *St., New York,* 36, *N. Y.,* $6.

The object of this new text is to acquaint the student with a formulation of quantum mechanics such that he can make applications for himself and can understand published work. He is assumed to have acquired a good working knowledge of elementary mathematical physics and to have some acquaintance with the phenomena usually included under the heading of "electron physics."

The book contains a deductive presentation of the wave mechanics form of quantum mechanics which should enable the student to understand the basic principled involved. It includes

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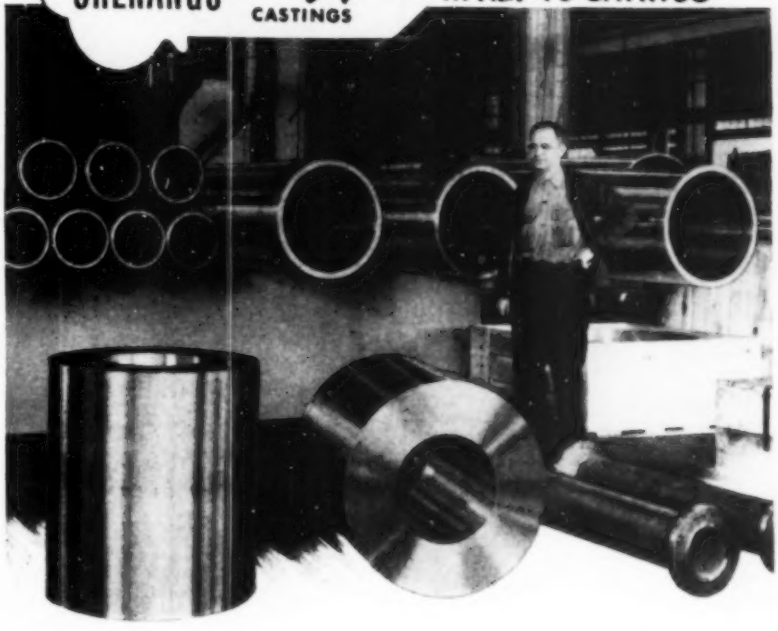

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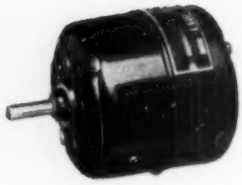
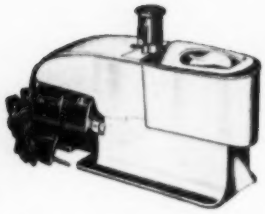


whip up a Lather



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a general outline of the basic theory development from two fundamental postulates followed by a series of illustrative applications. These applications give an introduction to the various fields to which nonrelativistic quantum mechanics can be applied. Mastery of the material in the book will enable the student to read research papers and to apply the theory himself to appropriate problems.

Presentation has been confined to the Schroedinger wave mechanics, although passing reference is made to other forms of quantum mechanics. Emphasis is placed on methods which are useful in each of the further fields of application.

A more extensive treatment of spectroscopy and electrons in solids is offered than is usually given in such books. Furthermore, a brief account of quantum statistical mechanics is included. The treatment is practical in the sense that it suggests practical methods for treating the theory of atomic, molecular and solid structure.

Numerous problems are attached to each chapter which not only illustrate, but develop the subject matter further.

Strength of Materials

Revised by E. K. HANKIN, *Coordinator, Murrell Dobbins Vocational School, Philadelphia, Pa. Eighth revised edition.* 148 *pages,* $5\frac{3}{4}$ x $8\frac{1}{4}$ *in. Published by John Wiley and Sons, Inc., 440 Fourth Ave., New York, N. Y. and Chapman and Hall, Ltd., London. Hard Cover.* $2.24.

In revising Merriman's Strength of Materials, the author has written an elementary textbook and gives all the practical aspects of material qualification and structural shape without becoming involved in complicated theoretical analysis. The highest form of mathematics used is algebra.

Where the meaning and derivation of the moment of inertia is explained and algebraic analysis and approximation for a rectangular section is offered, reference is made to the more accurate calculus method with a chart that gives the values for several more complicated sections.

Chapter I briefly reviews the reasons for considering the shape and application of a structural member as well as the properties from which the member is made. Chapter 2 defines the properties of materials and explains the reactions of solid bodies to external forces.

Tensile, compressive and bending loads are covered in Chapters 3 to 7

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To check this part completely and accurately by usual methods, you might need as many as two dozen or more different gages—and you still wouldn't be sure all corners were sharp, all angles and radii exact. There's a much faster, more accurate way to do the job completely, one that requires no mechanical gages that can lose accuracy through wear.

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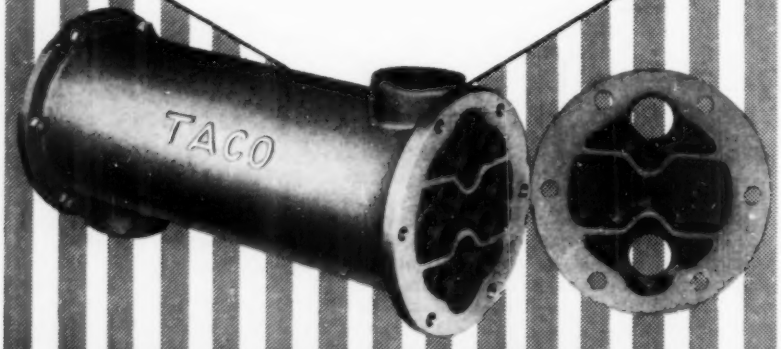

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with many force and sheer diagrams to illustrate the methods of analyzing the various conditions. In this section the moment of inertia and location of a center of gravity are explained.

Chapter 8 includes illustrations of strength of material quantities to such miscellaneous applications as pressure in cylindrical sections, riveted and welded joints, bolts and machine screws and shaft couplings.

Structural qualities of compound members such as reinforced concrete and "flitched" beams are given in Chapter 9. Chapter 10 is on combined stresses and Chapter 11 discusses the resilience of materials.

Appendix A gives a general description of the various industrial materials in paragraph form and in Appendix B the actual structural values are tabulated.

Each article and chapter in the book is followed by a short section of pertinent questions and problems. An index is included for alphabetical reference to many of the important points mentioned in the book.

Television Engineering

DONALD G. FINK, *Editor, Electronics, Second edition,* 721 *pp,* 6 x 9 *in. Published by McGraw-Hill Book Co., Inc.,* 330 *W. 42 St., New York,* 36, *N. Y.,* $8.50.

For technical workers who want to add familiarity with television engineering to their knowledge of radio engineering—for readers who want adequate self-training material for engineering jobs in television broadcasting and manufacturing plants—for college and technical institute students in this field—this book meets the need for grounding in the engineering and technical fundamentals of television.

The whole television process, from studio to receivers is covered. Aspects peculiar to television technology, such as scanning and waveform analysis, illumination and colorimetry, and camera tubes and picture tubes, are treated in detail, starting from first principles.

The principles of operation of television systems, in black-and-white and color, are covered, and the book describes in detail the design, operation, and use of television equipment. In addition to the explanations of basic principles and theory, practical working diagrams are given, complete with all values of parts, tube types, etc., for all functional elements of the television system, including studio and field cameras and associated equipment,

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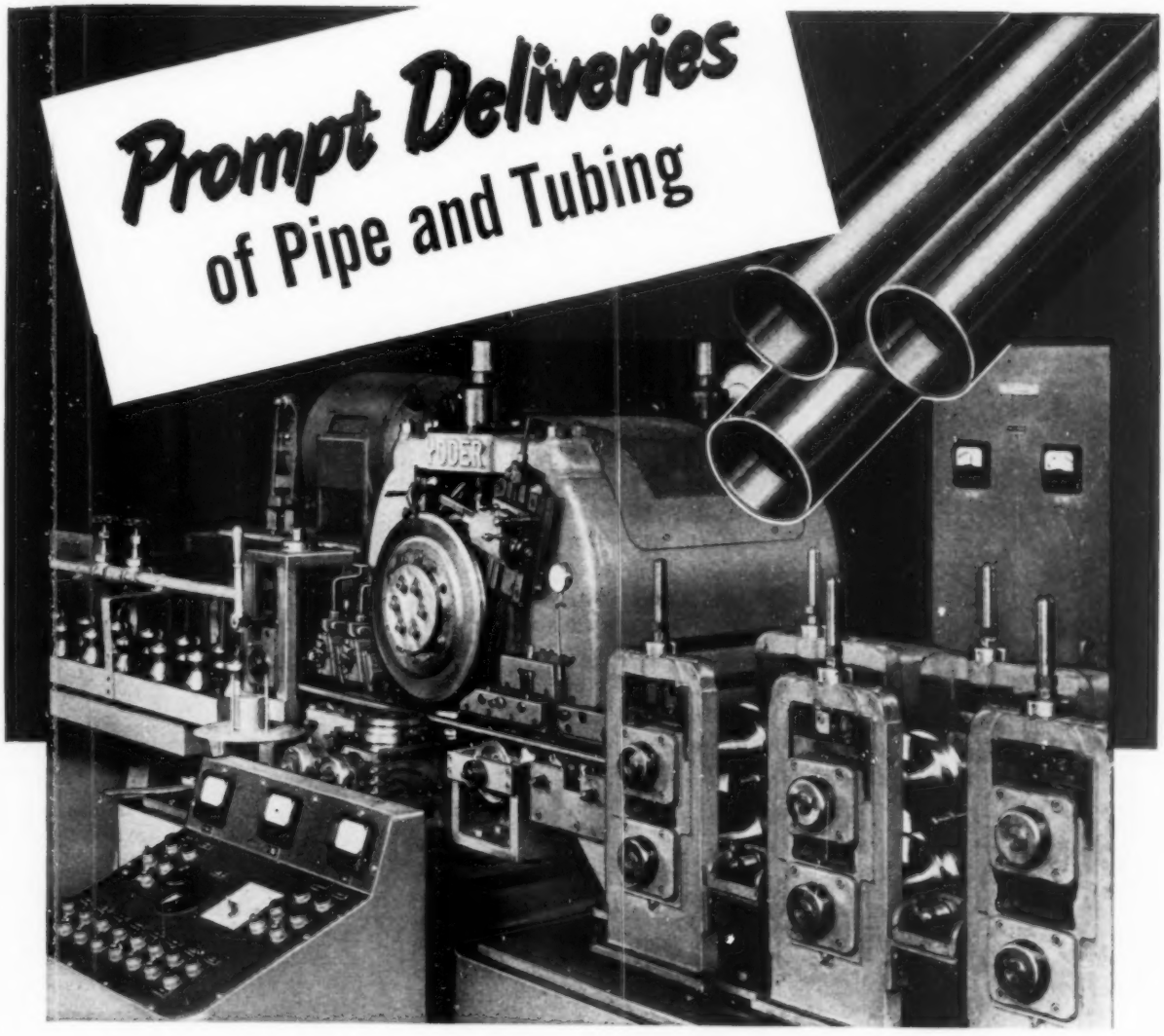

may be realized by installing a low-cost Yoder Cold-Roll-Forming, Electric-Weld Tube Mill. Cold or hot rolled strip is fed continuously into the mill, coming out as finished pipe or tubing, automatically cut to length.

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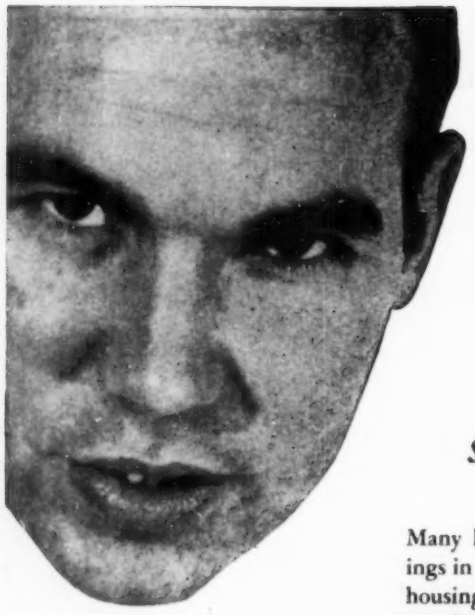

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A guide rail on the inside diameter of the outer race maintains roller alignment. Normally, no correction is required. Should misalignment cause tendency to skew, the guide rail touches grooved rollers back into position by momentary contact at Y. Arrow X indicates the direction of rotation.
X
Y
Fig. A
Fig. B
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Two chapters on color television, including description of six systems, are part of the hundreds of pages of new and fully rewritten material in this edition. Intercarrier sound reception, distributed amplification, stagger tuning of i-f amplifiers, the keyed clamp circuit, tonal gradation correction amplifiers, and u-h-f and s-h-f transmission equipment, are among the many recent developments covered in the book.

Receiver Circuitry and Operation

ALFRED A. GHIRARDI *and* J. RICHARD JOHNSON. *669 pages, 6x9 in. Published by Rinehart Books, Inc., 232 Madison Ave., New York* 16, *N. Y.* $6.

This book is a basic coverage of modern television and radio systems and receivers. The treatment is practical, written for the radio service technician, the student, and the radio experimenter, and the coverage includes the latest developments in circuits, antennas, materials of construction, principles of operation and explanations of the AM, FM, and TV forms of transmission. Because of their importance in the servicing and other fields, modern recorders, record changers, and pickup devices are also thoroughly discussed, with information on new magnetic recording devices.

All types of circuits now in use in home receiver installations are explained, up to and including the latest designs. Throughout the book, the treatment is nonmathematical and couched in terms familiar to all radiomen. A glossary of terms at the end of the text provides the beginning radioman or student with immediate clarification of words or expressions.

How To Supervise People

ALFRED M. COOPER, *Desert Center, California. Third edition, 254 pp, 5x7 in. Published by McGraw-Hill Book Co., Inc., 330 W. 42 St., New York* 36, *N. Y.*, $3.75.

This book gives practical hints for the present day supervisor in an easy reading, fast moving style. It covers all the typical jobs and problems of hiring, discipline, preventing accidents, promoting teamwork, training workers, delegating authority, labor relations, etc. It makes plain helpful techniques for handling them, with

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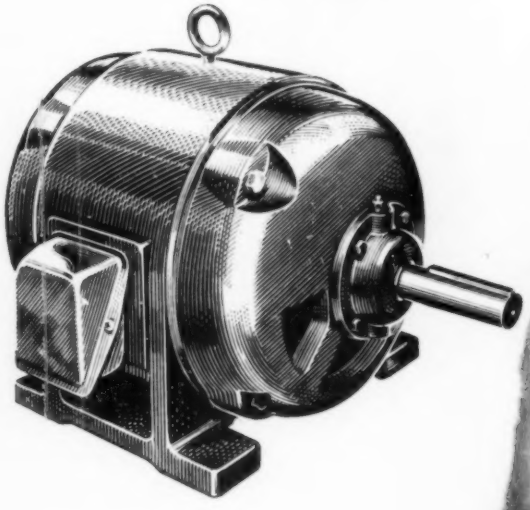

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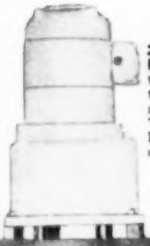

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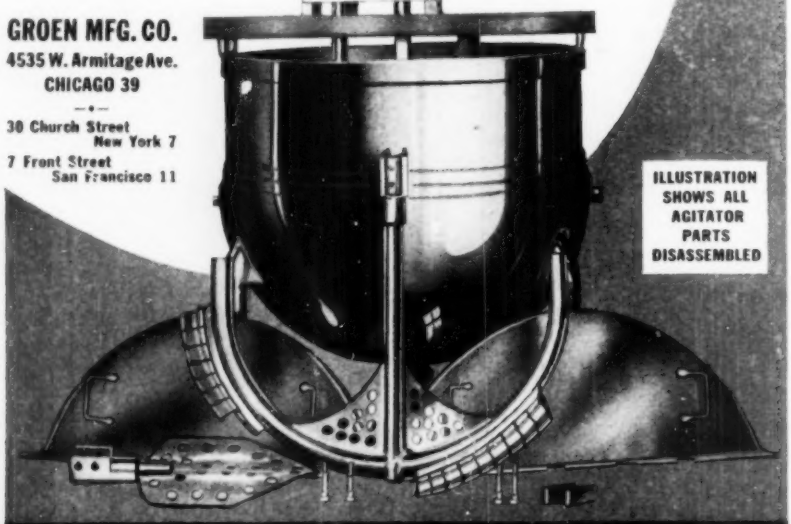

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In this latest edition, the book has been largely rewritten to bring it into line with todays conditions. A discussion of the Taft-Hartley law as it affects the supervisor, an outline of a program for employee participation in management and other case examples have been added. These give the foreman or office supervisor answers to those problems which he will have to solve this year or next year.

A chapter of questions for group discussion is included at the end of the book. This can be used as the basis of a conference training course for supervisors.

Performance of Lubricating Oils

H. H. ZUIDEMA, *Shell Oil Co. Research Lab.* 179 *pp.* 6 x 9 *in. Published by Reinhold Publishing Corp.* 330 *W. 42nd St., New York* 36, *N. Y.* $5.

This book treats the subject of lubricating oils from the point of view of performance rather than specific applications. Discussion includes separate chapters on the following: the rheology, oxidation, corrosion, emulsification and foaming, wear, sludge and lacquer deposition, and manufacturing methods.

The material on corrosion includes a comparison of the corrosion resistance of several commonly used materials as well as the basic mechanisms of the three types of corrosion; acid, sulfur, and aqueous acids. The chapter on manufacturing methods points out the effects of the various steps in the process of manufacturing oils on the performance characteristics of the final product.

Each chapter in the book is supplemented with a comprehensive bibliography to facilitate a more detailed study of the different factors that are discussed.

Register of British Manufacturers, 1951-1952

24th Edition, 882 *pages,* 9½ x 7½ *in. Published by Kelly's Directories Ltd. and Iliffe and Sons Ltd, Dorset House, Stamford St., London, SE* 1, *England.* $5.88.

This is the authorized directory of the Federation of British Industries, the largest association of British manufacturers, and is recognized as a standard export reference book to British

industry. The information is classified for quick-reference in English, French and Spanish. The volume provides a substantial cross-section of the most important producers of British goods over a wide range of industry.

It comprises seven sections; (1) Products and services—which is a classified buyers' guide listing 6,000 FBI member firms under about 5,000 alphabetical trade headings; (2) Advertisements—produced in colors, constituting an illustrated catalog of British products; (3) Addresses—an alphabetical directory of all FBI member firms with their full addresses, telegraphic addresses, telephone numbers, list of products, and in many cases their home and overseas branches, agencies, etc.; (4) Trade associations of England listed alphabetically according to products and services; (5) Brand and trade names; (6) Trade marks, an illustrated section alphabetically arranged by products; and (7) Addendum, where details are listed of new FBI members elected after the main sections of the book were closed. All sections have reinforced guide tabs for quick reference.

In a short introductory section in the front of the book is a foreword by FBI president Sir Archibald Forbs, an organizational chart of the FBI and several short editorials on the aims and activities of the organization.

Laminated Plastics

G. S. LEARMONTH. 268 *pp. Leonard Hill Limited, 17 Stratford Place, London, W. 1., England.* $4.90.

This book is a survey of the materials, methods, and products of the part of plastics industry involved with the formation or use of laminated sheets, tubes and moulded articles. It is drawn largely from published information in the technical press or in the data sheets issued by the manufacturers of resins and laminates.

The book is addressed primarily to the less senior technicians in the laminated plastics industry and related industries. The author has tried to offer something to the non-scientific personnel connected with the manufacture and distribution of laminated as well as other plastics in the industries using them. This volume should be of interest also to those members of the general public who are interested in plastics and their applications.

The text describes the laminated plastics industry existing in Britain at the present time with additional information on the American side of the industry. All essential fields of the

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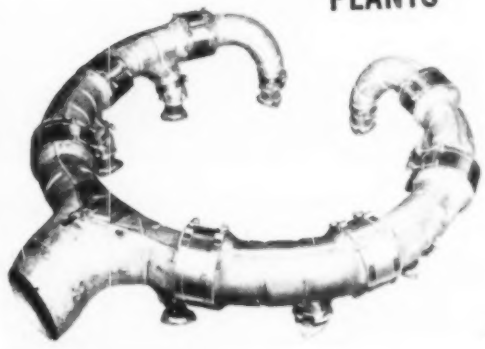

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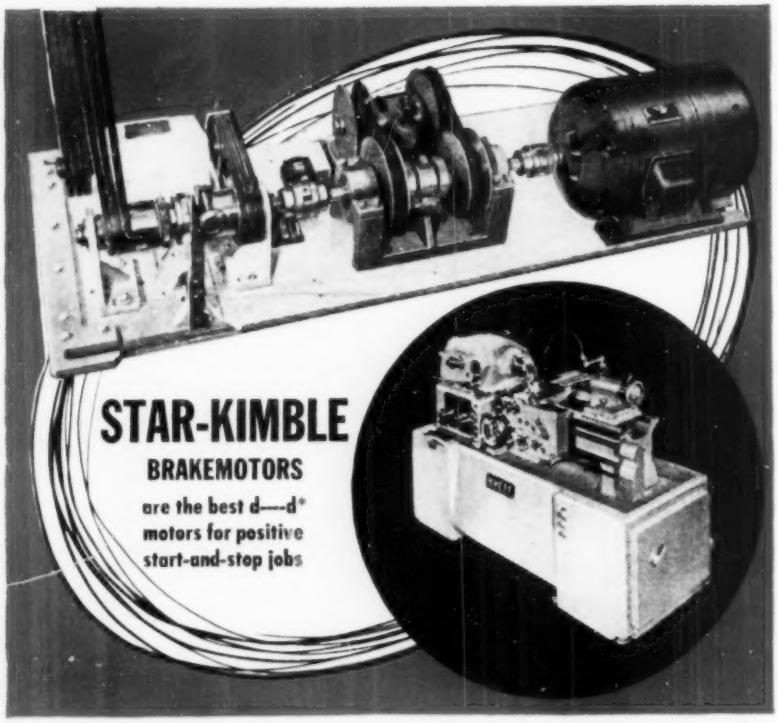

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industry are covered without involving details which are special to the individual processes.

The properties of the different types of laminates, the effects of filler materials and general rules for machining are included. A large part of the book is devoted to the constructional electrical and industrial applications of laminated plastics.

Many graphs and figures are presented to illustrate specific points. Important data on commercially available products is tabulated in the appendix.

Trigonometry, Plane and Spherical

LLOYD L. SMIL, *Ph.D. Professor of Mathematics, Lehigh University.* 406 *pp.* 6 x 9 *in. Published by the McGraw-Hill Publishing Co.,* 300 *W. 42nd St., New York* 36, *N. Y.* $3.75.

A comprehensive treatment of plane and spherical trigonometry, this text is intended primarily for use in colleges and technical schools, but can also be used for substantial courses in secondary schools. The aim is to give a well-rounded course that is teachable and accurate according to modern methods. Attention is given to both the numerical aspects of the subject and the analytical considerations. A variety and number of exercises are also included.

Besides considering all basic factors of trigonometry, one chapter is devoted to complex numbers and one to logarithms. Tables of logarithms, squares, square roots and trigonometry fractions are also included.

Principles of Electrical Engineering

GROVER C. BLALOCK, *Professor of Electrical Engineering, Purdue University. Third Edition,* 605 *pp.* 6 x 9 *in. Published by McGraw-Hill Book Co., Inc.* 330 *W. 42 St., New York* 36, *N. Y.,* $6.50.

This textbook is based upon the experience of the author in the teaching of non-electrical courses—the courses in theory and application given students whose major work is in civil, chemical, or mechanical engineering schools or departments. It attempts to present fundamental principles in concise form, with frequent references to practical application. Examples, illustrating applications of principles, are used freely and many of the chapters are followed by a list of practice problems, with data such as would be se-

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Fig. 1

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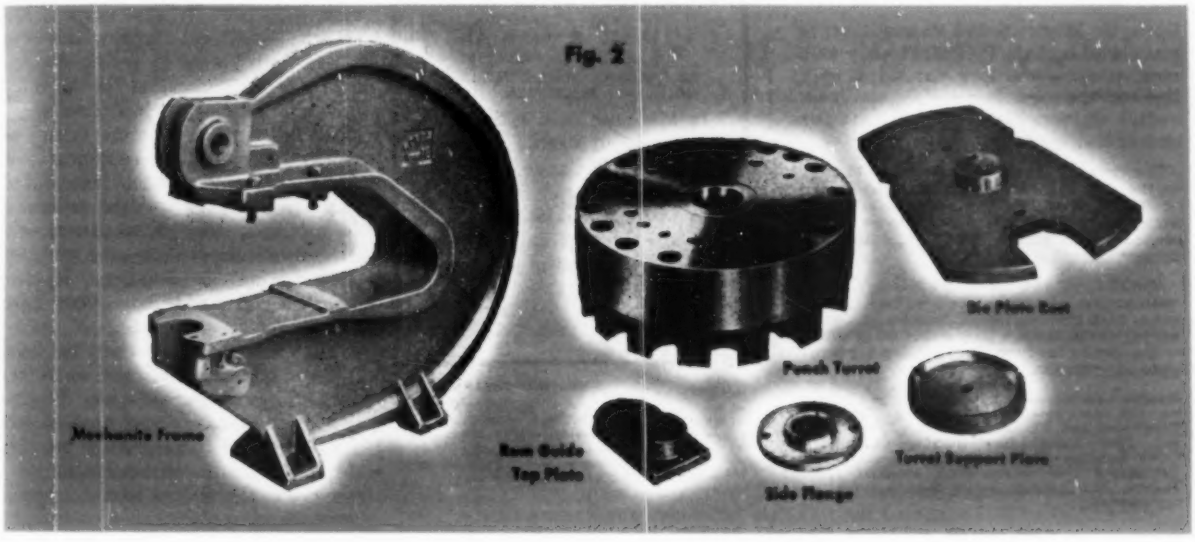

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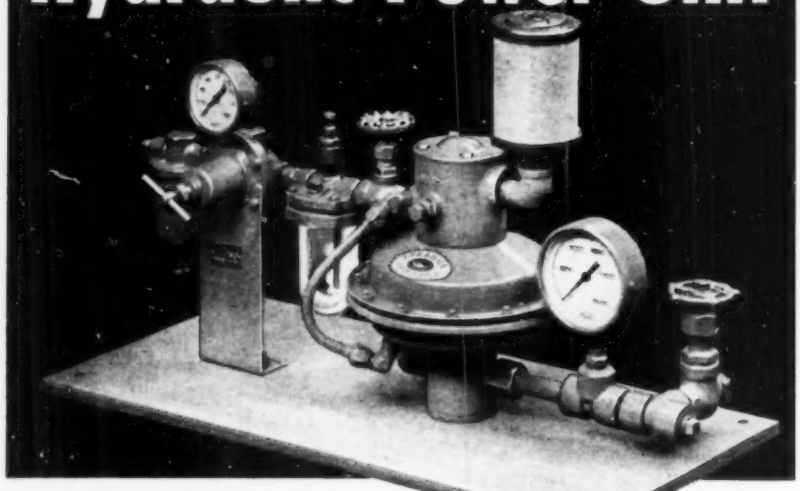

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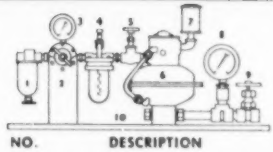

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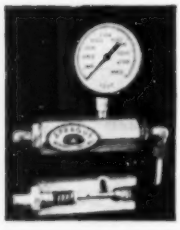

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cured under practical working conditions. It is assumed that the student will have had the usual freshman and sophomore courses in physics and mathematics although these are not entirely essential to an understanding of the subject matter presented.

In the third edition the author has endeavored to amplify and modernize the text without altering its general plan. All material has been carefully reviewed and additional material has been inserted at many points. Illustrations have been brought up to date, and an attempt has been made to bring nomenclature and graphical symbols into line with current standards. Most of the practice problems have been altered by the substitution of new data or improved as to statement, and many entirely new problems have been added.

The magnetism and electromagnetism chapter has been combined with the chapter on magnetic circuits, and additional material on growth and decay of current in inductive circuits added to the chapter on electromagnetic induction. A new chapter, Dielectric Fields and Circuits, has been added, with a view to giving the student a better foundation for the study and understanding of electronics equipment and circuits. For the same reason the superposition, reciprocal, and Thevenin theorems have been added in a later chapter and the treatment of networks, both direct-current and alternating-current, considerably expanded. Suitable problems, in line with the text additions, have been added.

The chapter on electronics has been enlarged and amplified both as to theory and practical application. Discussion of the mercury-pool type of rectifier has been transferred to this chapter, with the application of electronic control devices added. Application of electronic devices in industry has been given particular attention.

Industrial Heat Transfer

F. W. HUTCHINSON, *Professor of Mechanical Engineering, University of California,* 336 *pp,* 6 x 9 *in. Published by The Industrial Press,* 148 *Lafayette St., N. Y.* 13, *N. Y.,* $6.

To simplify the solution of problems on heat transfer between industrial fluids, Professor Hutchinson has reduced the complex formulas and time consuming work on density, specific, and viscosity down to 128 working charts. From these charts can be obtained a direct solution of heat transfer problems for 70 industrial

fluids ranging from air and acetylene to sulfur dioxide and water. These graphs are as accurate as the equations from which they are derived. As an additional aid, the page opposite each graph gives the equation for the graph, its limitations, its extension, and the references to the discussion of that equation in the text. An actual example is given, and its solution shown.

The six chapters in the book are: Introduction, Conduction, Radiation, Convection, Combined Heat Transfer, and Forced Convection.

Each chapter consists of three parts. At the beginning the fundamental theory is discussed, and the equations relating to the evaluation of heat transfer coefficients and rates are developed. At the end of the chapter are presented the graphs referring to these theories and equations.

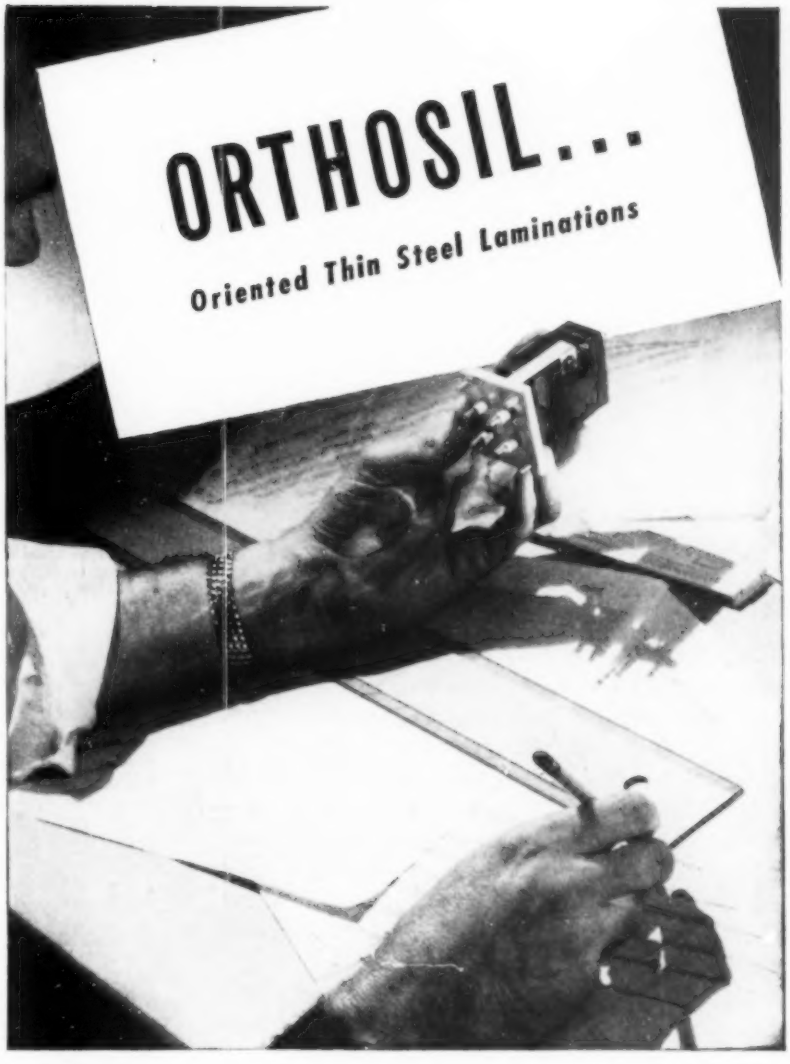
Production of Motor Vehicles

HENRY M. CUNNINGHAM, *member of Munitions Board of the Defense Department and* WILLIAM F. SHERMAN, *Manager of Engineering and Technical Department, Automobile Manufacturers Association.* 169 *pages,* 6 x 9 *in. Published by McGraw-Hill Book Co., Inc.,* 330 *W.* 42*nd St., New York* 36, *N. Y.* $3.50.

This book studies the successive management steps required to plan and to bring into production a new-model automobile or truck. Here is an outline of the over-all management "know-how" needed to meet production problems quickly.

It describes the preliminary activities of sales, engineering, and purchasing department; discusses the initial survey to determine plant, equipment, and manpower requirements; the production of detailed drawings and specifications, designing and making tools, selection and procurement of machinery, etc.; and final cost determination and scheduling of actual manufacture of new models. The book also gives a concise analysis of the methods used in quantity, quality, and cost control. A final chapter covers the relationship of dealer orders to scheduling, and the role of the traffic department in shipping.

About 500 drawings and photographs have been integrated with the text to illustrate typical office forms and drafting procedure used in automobile plants and the photographs show how some of the engineering work is actually done. Near the center of the book is a two page spread that graphically traces the motor vehicle assembly line from start to finish.



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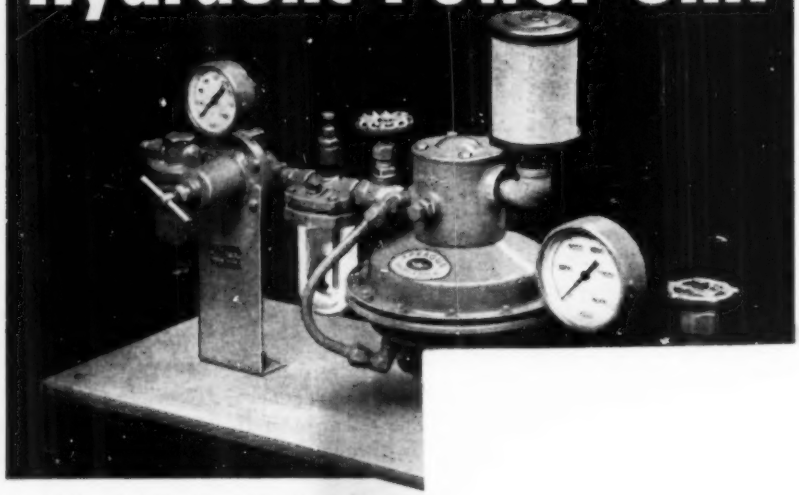

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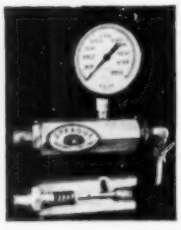

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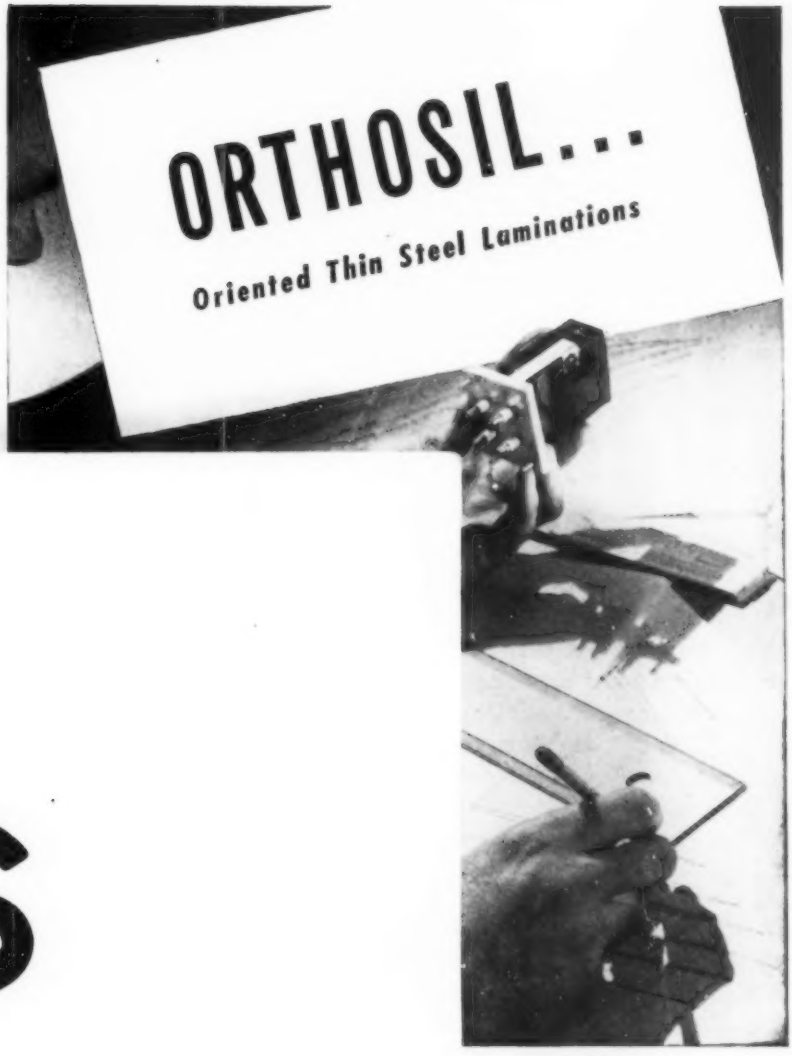
The six chapters in the book are: Introduction, Conduction, Radiation, Convection, Combined Heat Transfer, and Forced Convection.

Each chapter consists of three parts. At the beginning the fundamental



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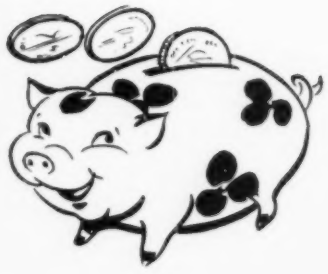

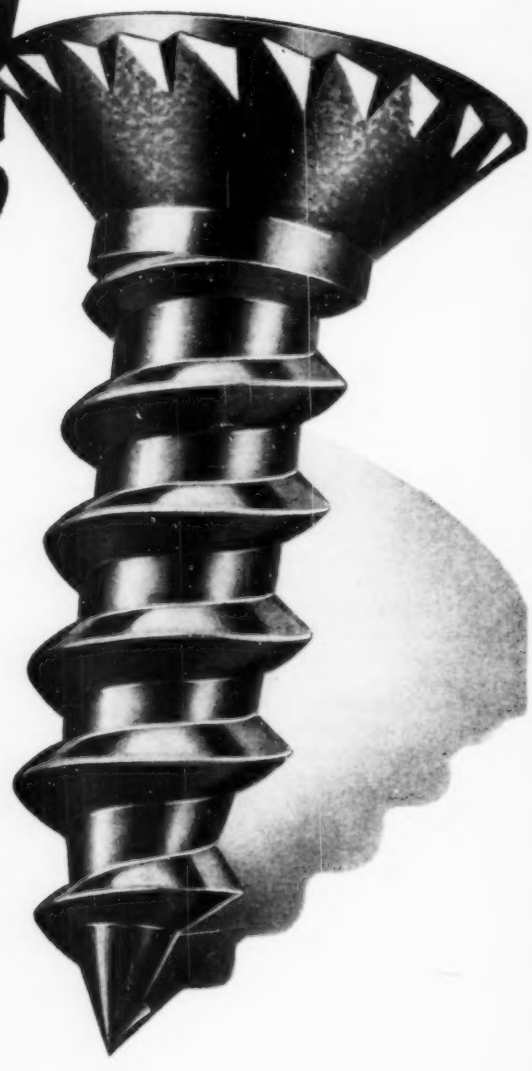

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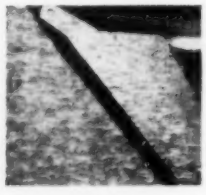
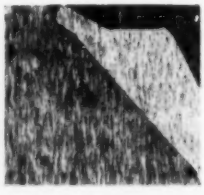


Teeth of SPIN-LOCK Screw touch bearing surface before final tightening.



Final tightening embeds teeth in surface, assuring positive locking.

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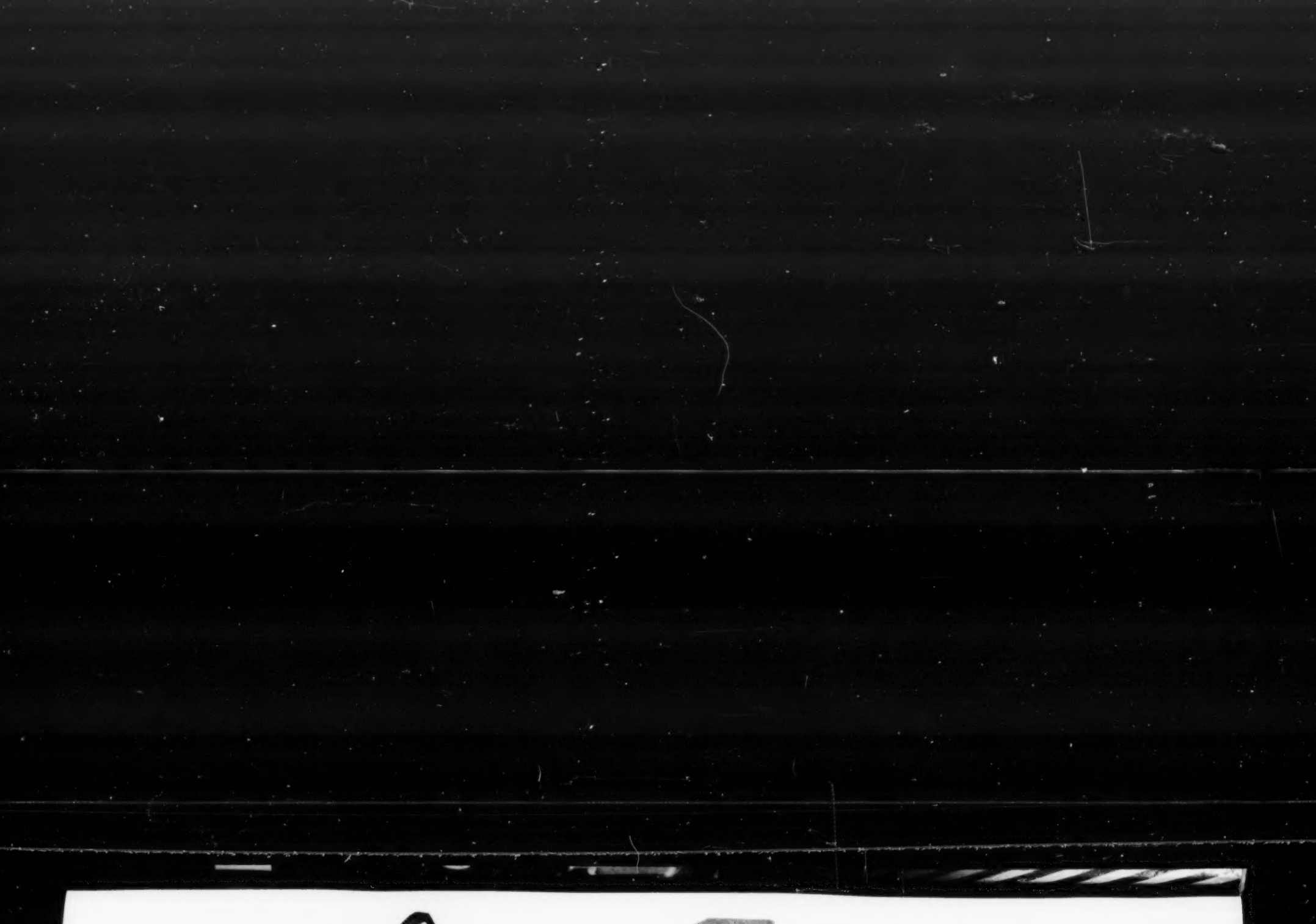
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